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By

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CHAPTER I

INTRODUCTION

Counts of traffic volumes comprise a major effort of state highway departments. These counts are used to present a picture of traffic volumes over all sections of road in a state. The average daily traffic is tabulated in forms such as the monthly and yearly daily average, by weekday and weekend, and a peak hour percentage of the average daily traffic.

Some of the uses for these counts are (1) highway usage classification, (2) design elements in highway planning, (3) accident rates, (4) maintenance priorities, (5) vehicle miles of travel(VMT), (6) travel trends, (7) market research studies, and (8) calibrating travel forecast models.

At present these counts are obtained using permanent counters at permanent locations and portable counters moved frequently to different locations to obtain a sample of vehicular traffic for all levels of roadways. These counts are expanded to give an average count for the different classifications of roads.

Theoretically, to obtain the perfect knowledge of the volumes of vehicles travelling upon all roadways, counters would need to be set up on every section of roadway in a study area with counts taken 24 hours of every day. This undertaking is not even remotely poss-

ible at present. Hence, sampling is used to obtain traffic counts.

Using West Virginia as an example, Lancaster(16) states that 3 years were required to secure traffic volumes for all 55 counties. Now that has changed to a 5 year cycle for all secondary roads in West Virginia. Lancaster further pointed out the major inadequacies of most existing coverage counts as: (1) full coverage count data are not obtained each year, and (2) it would prove prohibitively expensive to provide the desirable annual coverage.

Aerial photography has been used in traffic studies for 50 years(13). Usually these studies have been limited to one roadway or small study area. One of the main reasons has been the data reduction problem. Simply more photographs could be taken than could be analyzed by operators in a reasonable amount of time and cost.

It appears advances in technology in the use of computers to scan photographs and identify vehicles can reduce the problem of data reduction. This fact may be the key to future expanded traffic counting programs.

Purpose

The purpose of this study is to propose a method of obtaining volume counts for roadways using aerial photographs plus existing traffic counters. The study will be limited to urban areas and specific classes of

roadways. The reason for doing so is to reduce to a minimum the parameters that can affect the variation of traffic flow.

The counts to be obtained are of daily traffic. Then these counts would be used in the same manner as are the counts obtained now by pneumatic tube counters. With more locations sampled, better knowledge of traffic along <u>all</u> roads in an area in terms of accuracy and flow patterns would result.

To use the aerial photograph method, it is planned to make use of the following knowledge.

1. An aerial photograph can depict an instant of traffic flow for <u>all</u> links in a study area.

2. Urban traffic follows daily and hourly variation patterns which are generally consistent and often predictable. (11:19)

3. The percent of total traffic occurring in any given period is approximately the same along any route. (11:19)

Therefore, if the pattern of time variation of traffic is known for selected links, then the approximate variation for all similar links in the study area could be estimated. To further refine the estimates on a link-by-link basis, the photographs could provide a precise count for a specified time for every link being studied. Combining these counts into a pattern, a

total count for the entire time period can be estimated.

This approach is somewhat analagous to the present counting methods. Permanent counters are installed at carefully selected locations to provide counts for all days in a year. Hence, variations of traffic flow due to time will be apparent. These counts are used to provide factors to adjust the short-term counts obtained by the portable counters.

This study will try to determine if the combined aerial photograph and tube counter approach is feasible and accurate in obtaining daily counts for links in an urban study area. If this approach is feasible, then the study will attempt to determine the smallest number of counts needed to produce volume estimates with a low percentage of error.

CHAPTER II

LITERATURE REVIEW

The literature review concentrated in four general areas. They are the following:

1. Traffic counting procedures,
2. Aerial photography in traffic studies,
3. Statistical approaches to traffic counts, and
4. Computer processing of aerial data used in traffic studies.

The review was an attempt to ascertain the studies conducted in each of these areas and to determine if any inter-relationships existed among the areas.

Traffic Counting

In the first general area, articles by Adams(1) and Gilbert(10) reported on studies in the area of expanding short-term counts to obtain daily volumes of traffic. The Traffic Count Reports(31) show the results of the traffic counts conducted by the West Virginia Department of Highways. Two FHWA documents(5), (11) pointed out the basic objectives and uses of traffic counts. These guides form the guidelines for the nationwide counting programs.

Aerial Photography

In the second general area, the pioneering effort of Johnson(13) laid the basic framework of using cameras for aerial studies of highway traffic. The studies of Cyra(8) provided insight into the accuracy of volume and speed measurements possible along a section of freeway in studying speed and density of traffic. He brought out the fact that to be most economical, the traffic engineer must study as many facets of traffic operations as possible from the photographs taken. Jordan(14) gave a case study of the use of aerial photography in the dense urban area of New York. He pointed out the great amount of detail available from photographs. His report dealt with a study known as Project Sky Count.

Peleg, Stoch, and Etrog(21) pointed out how a relatively small team can make a comprehensive urban study in a short time by using aerial photographs. They developed mathematical relationships to determine traffic flow, traffic density, average speed, average travel times, and traffic composition. They provided information relating to flight planning, duration, and photo scale.

The parking study reported on by Syrakis and Platt (30) pointed out the tremendous savings in cost and time in using aerial photography to study on- and off-street parking in the central districts of three Ohio cities. They estimated an 85% savings in time and a 72% savings

in costs as compared to standard parking studies.

Trieterer(32) used aerial photography to obtain continuous traffic data on the general behavior of vehicles in platoons on two urban freeways in Columbus, Ohio. The knowledge obtained from aerial surveys and his research on traffic dynamics was used to develop a ramp metering system and a loop detector for density and speed measurements.

Wilson(36) used aerial photography to obtain measurements of 10 parameters of traffic flow in a small urban area. Among those parameters was an estimate of daily volume. The project proved that data could be collected by an aerial method and have a level of accuracy acceptable for traffic surveys.

Smollen(28) gave hope that a new traffic survey system tremendous in scope is almost here. This was used in the innovative New Orleans STAR Project. Not only traffic studies, but many other measurements related to urban life and planning were available from the use of aerial photography. In this project, recent developments in optical scanning and use of computers made the task of data reduction much easier and faster.

Ruhm(26) pointed out the advantages of aerial photography in traffic and land use studies. Likewise, the article by Moore and Wellar(18) pointed out the potential uses of airborne sensors throughout the urban environment.

They stated that "...as technological advances are made, yielding better imagery outside the visible range of the electromagnetic spectrum, our ability to identify and interpret will rapidly improve."(18:43) In fact, the major obstacles of weather and darkness may be overcome in the near future to provide a full-time look at urban dynamics.

Turpin(33) gave a comprehensive overview and evaluation of the uses of aerial photography in transportation.

Sampling

For the third general area, the two Guides(5), (11) by the FHWA gave the parameters for sampling traffic flow. They provided guidelines for selection of samples to provide accurate estimates of the traffic flows.

Muranyi(19) showed the importance of systematic sampling. He pointed out the value of grouping of like types of roadways. He also did research on finding the best times to conduct a count to get an approximation of the average traffic flow.

The book by Votaw and Levinson(34) has been used as a basic reference in traffic sampling.

A publication of the West Virginia Department of Highways(27) gave a practical application of traffic counts based on Federal guidelines for a statewide system

of roads.

Covault(6) gave a very practical aspect of the sampling theory in his discussion of estimating total costs of highway, bridge, and railroad crossing improvements on a statewide basis.

Computer Systems

Two traffic survey systems were studied. The system described by Raudseps(23) used a flying spot optical scanner. The operator identified ground reference points and vehicles. The machine then did the job for which it is best suited-calculation. It correlates the film coordinates to ground coordinates, keeps records, and tracks vehicles through the succession of photographs.

The system patented by Kerr(15) used two transparencies for comparison. The transparencies were made from the same aerial picture of a selected area. One transparency has all areas other than roadways made opaque by the operator. This transparency is used as the basis for comparison. The two transparencies are optically compared in order that only objects on roadways are detected as significant data. A monochromatic light beam is used as a scanning beam. A set of holographic replicas of different size vehicles is sequentially interposed in the scanning beam for each increment of roadway sample. When the filter size corresponds to vehicle size,

there is more light passed through the filter than the normal intensity of light. By detecting this increase in intensity as a vehicle, the computer stores vehicle location and size in a memory. The computer then calculates traffic densities and can track vehicles on successive photographs. This system can be developed further using technology based on liquid crystals.

Treiterer(32) developed computer programs for data processing and data presentation for his study of vehicle trajectories. In his study, each vehicle was uniquely identified by the operator. The photo coordinates were stored in a computer. A computer program then produced output on vehicles, coordinates, spacing, headway, velocities, density, and volumes, The data reduction rate was about 30 minutes per photograph because of the required man-machine interaction.

Ashbaugh(2) in his thesis used a flying spot scanner to scan transparencies to find man-made objects. In this study, the transparency was represented by a 15 gray level printer program. This was then contoured using an equation representing the sum of local vertical and horizontal gradients around a point. A 5 gray level contour map was produced. The Fast Fourier Transform was used to find a correlation of contours with selected rectangular prototypes. A closed curve was traced through the contours showing a high coorelation. If the loop was closed,

then the object was assumed to be man-made. Each detected man-made object had its boundary plotted by a Calcomp plotter along with a decision as to what the object represents. Perhaps future research along this line will lead to automatic detection of vehicles on roadways because of the readily identifiable shapes of vehicles.

Summary

The literature reviewed has provided a very good background on traffic counts and aerial photography. There are many researchers genuinely enthusiastic over the promises shown by counting from the air. By reducing costs and time needed to count vehicles, present systems of traffic counting can be expanded to provide very accurate counts for all roads on shorter counting cycles.

CHAPTER III

AN APPROACH TO THE PROBLEM

To obtain traffic counts today, the agency making the counts usually uses pneumatic tube counters and/or electronic loop detectors. They use a network of roadways, such as a state, for the population of roads to be sampled. The roads are classified by a system designed to provide basic functional classes of roads. Each of these classes of roads is then sampled to obtain a representative traffic count. After sampling, an estimate can be made of the total number of vehicles that are using all roads in that class throughout the study area.

For example, the West Virginia Department of Highways obtains a count of 48-hour duration at its portable tube counter locations. There are proportionately more counters on roadways in the lower ranges of volumes in order to obtain counts of required accuracy.

The DOH also uses permanent counters installed at specified locations to give a record of all traffic passing these locations throughout the year.

Other inputs are available to the traffic counting agency. Past counts are used as trend forecasts. Seasonal counts are made to determine the variations due to time of year. These seasonal counts are especially important on routes used in recreational areas.

All these inputs result in factors that are applied to the sample counts. The end result is an estimate of Average Annual Daily Traffic(AADT) for the links of the highway or street system.

In the West Virginia Traffic Counts, the resulting traffic estimates are arranged by roads in a county. In this arrangement, the section of road, length of link, the AADT, peak hours, peak hourly volume, and peak hour percentage are arranged in columar form.

There is a yearly summation of road mileage and vehicle travel in the West Virginia Traffic Count Report also. Here, the highway system is broken down by usage and by State or Federal designation. Miles of road in the State are given for each classification. Annual vehicle-miles and daily vehicle-miles per mile for each classification are also given.

With this information, an engineer can total the miles of roadway in a particular study area, classify by usage, and then use the reported figures to obtain an estimate of vehicle-miles of travel in that area.

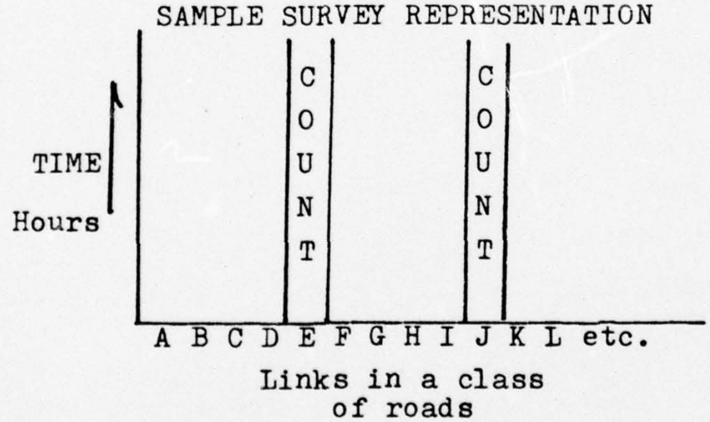
This information can further be used to provide estimates of air pollution and fuel usage. These latter estimates are becoming more and more important in light of today's environmental statutes and energy considerations. Priorities on maintaining or upgrading certain roads could be formed knowing the usage of these roads.

Counting by Sampling

Suppose one wanted to find volumes for the arterial streets in an urban area. The total length of this particular class of roadways in the area would first be defined. To get a count of traffic, portable counters must be set out to record the vehicles as they pass over the streets. To be truly accurate, one would divide the roadways into links of approximately equal lengths and then place a counter on each link. But, this could lead to an enormous project. Since time, money, and manpower are quite real constraints, the use of sampling is the preferred course of action.

FIGURE 1.

SAMPLE SURVEY REPRESENTATION

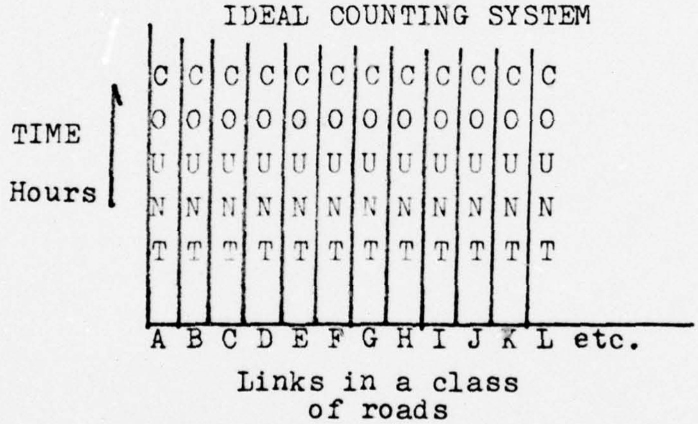


The results of a sample survey are shown in Figure 1. A vehicle count of links E and J over a time period is shown. The links counted are chosen by statistical methods to represent all links in this class of roads.

The other links in this class have no counts taken during this time period. By carefully classifying the roads into common classes, one can assume the other links of this class behaved in the same way with approximately the same numbers of vehicles using those links. This is the assumption governing the counting of traffic today. Sampling to obtain an average amount of usage and then multiplying by the total miles of that class of road is the method used to arrive at an estimate of VMT for the class for the entire study area.

FIGURE 2.

IDEAL COUNTING SYSTEM

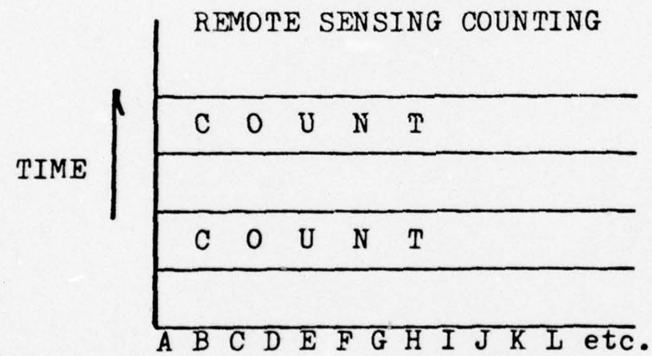


In Figure 2 the ideal counting system is shown. A counter for every link is recording vehicles throughout a specified time period. Restrictions of both manpower and costs make this type of counting infeasible, however.

Counts in a Short Time Period

In Figure 3 the counting of traffic by remote sensing is shown. The count is only for short time periods simulating the traffic counts obtained by aerial photographs. From the vantage point of altitude, one can study all links of roadway in an area. An aerial photograph or series of photographs can look at only a short time span of vehicle movements. But with proper interpretation, all vehicles that are in position to be recorded can be counted.

FIGURE 3.



Links in a class of road

To obtain a perfect count in this fashion, a system of recording would be needed that recorded continuously from beginning to end in a counting period. A system such as this using aerial photographs is not feasible either economically or technically at present. Therefore, sampling of all links by short intervals of time is

proposed for use much the same way current counting practices use samples of lengths of road counted for 24 hours or 48 hours at a time.

A Combination Approach

This thesis proposes that traffic counts of an area can be obtained by using a combination of link sampling by mechanical counters and area sampling by aerial photographs.

FIGURE 4.

COMBINATION OF REMOTE AND MECHANICAL COUNTING

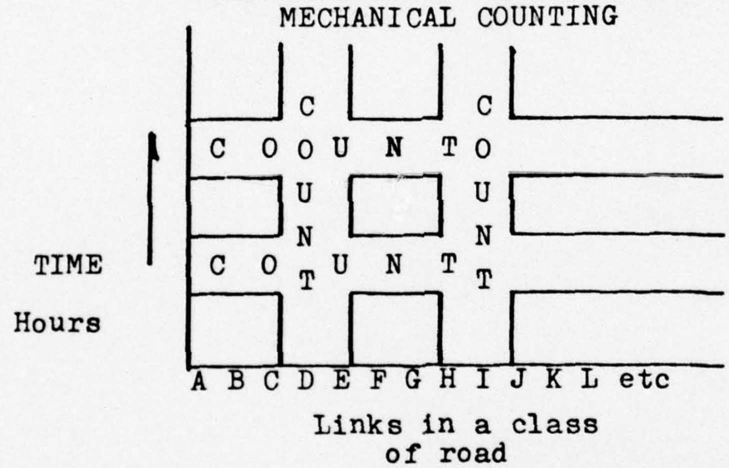


Figure 4 shows the basic principle. If one can obtain an accurate count on several links throughout a day-long period and then combine with this accurate counts of all links in the area for short time periods, then one could build a matrix containing values for all

links throughout the day-long counting period. This matrix would be completed using the broad guidelines of the FHWA that are listed below.

Guidelines

The Guide to Urban Traffic Volume Counting prepared by the Federal Highway Administration gives the following findings:(11:19,20)

1. Urban traffic follows daily and hourly variation patterns which are generally consistent and often predictable. Urban traffic volume patterns exhibit relatively little weekday and seasonal variation. The per cent of total traffic occuring in any given period is approximately the same along any route.

2. The more counts, even though of a very short duration, the greater the reliability of the resulting estimate. Similarly, the heavier the traffic volume at a particular location, the greater the reliability of a given sample.

3. The distribution of counts throughout a day is more significant than the total time during which the traffic is counted. The number of separate and independent observations is more important than the number of hours of each observation.

4. As counting locations are combined, the sampling variability resulting from short-counts diminishes.

5. Stratified sampling techniques have merit over simple random sampling in estimating VMT, since they reduce the variation within parts of the total sample.

6. Sampling more locations, each for a shorter period of time, will likely result in less error than sampling a few locations, each for a longer period. This implies maximizing the number of different locations sampled.

The preceding broad guidelines serve as a map for this experiment. Short counts, as representative of the counts obtained by aerial photos, over a large number of locations coupled with the knowledge of hourly and daily variations of traffic flow should provide the basis for a reliable estimate of VMT for an area.

CHAPTER IV

ANALYTICAL TOOLS

Use of Patterns

Over the years, there have been numerous studies analyzing traffic flows and their hourly variations. Nearly every traffic study has charts of traffic flow versus hour of day or trip ends versus hour of day to show the pattern of traffic in the study area. In the Transportation and Traffic Engineering Handbook published by the Institute of Traffic Engineers, there are several graphs showing these patterns in the chapters on general and urban travel characteristics. While varying from city to city, urban traffic in a specific area is generally consistent, as pointed out previously. Therefore, if one can ascertain a pattern to the traffic flows being studied, then flows of traffic in the same area can be estimated. This is one premise this experiment will attempt to prove.

Muranyi(19,20) has made in-depth studies of this pattern phenomenon in both Europe and the United States. His work led to his proposals of traffic volume estimates based on factors of road classification and time variation.

Aerial Counting

While it is technically possible to obtain a full hour of photographs of a highway network at one time, the cost of such an approach would be enormous. First, there would be the cost of the film. Exposures need to be taken every few seconds to be able to follow individual vehicles. An hour's worth of film for this many exposures would require many feet of film and space to store it. The magazines of aerial cameras simply do not have this capacity.

Secondly, the space traversed by the platform used for photography has to be considered. The fixed wing aircraft covers distance quite fast. Flight patterns can be arranged to photograph the same area, but at the cost of some coverage.

The helicopter has been used in quite a few experiments. It has the ability to hover over one area or to follow the flow of traffic. It is not a steady platform and flight duration is a factor in the longer counts.

In the New Orleans STAR Project, the Goodyear blimp was used in obtaining photographs. The blimp proved to be a steady platform for photography, of fairly long endurance, and relatively economical. It does have limits on the altitude that can be reached and weather affects operations.

Satellite Observations

After studying the available literature, the use of satellites in traffic observation has to be ruled out for the present time. The main reason is resolution. The resolution available to non-military users is too poor for use in counting vehicles.

Another reason is coverage. Orbits cover a specific area on the earth's surface only for a few minutes each revolution. The earth resources satellites cover the entire earth with their orbital paths as each successive orbit shifts westward. Consequently, they pass over a specific area of the earth only once every 18 days. However, cloud cover generally reduces coverage to some multiple of 18, depending upon geographic location.

In the report(12) of remote sensor imagery used in the Tellico area of Tennessee, the researchers concluded they could not use the images that would be produced by satellites. They used photographs taken from aircraft to simulate the images that would be available from satellite observations.

Aerial Photography

For this experiment, aerial photography was chosen as the form of remote sensing that could be used in connection with traffic counting. One reason is the amount

of equipment and information available in this area. Costs are low. Another reason is that computer systems being developed use film as the method of recording the movements of vehicles.

Advanced sensors such as infrared scanners, television, or multispectral sensors have not been developed to the point where they would be a viable economic alternative to the aerial camera in recording traffic flows.

Because of the unknown areas of this research, the experiment has concentrated on using material that is familiar to most people engaged in traffic counting. Hence, aerial photographs and contemporary traffic counters are addressed in this experiment.

Simulation

In order to simulate the counts available from aerial photographs, hourly counts taken from pneumatic counters will be used. This simulates the short counts of aerial counting. While the short counts available by aerial methods are not of an hour's duration, the basic idea of obtaining a fraction of the vehicular traffic and then estimating the total count for 24 hours can be shown by using the hourly counts. From that point, it is simply an extension of the basic process to expand a count of less than an hour to an estimate of a 24 hour count.

There is further discussion of this in the section on future research.

CHAPTER V

THE TESTING

This study shall test the hypothesis that traffic counts of an area can be obtained by using a combination of link sampling by mechanical counters and area sampling by aerial photographs.

First, counts of roads that are close spatially and carry the same general levels of traffic are selected. Counter records supplied by the West Virginia Department of Highways are used for data and are shown in Table 1 in the Appendix. The area used for study is the city of Morgantown, West Virginia and surrounding area. This area has a population of approximately 50,000 people.

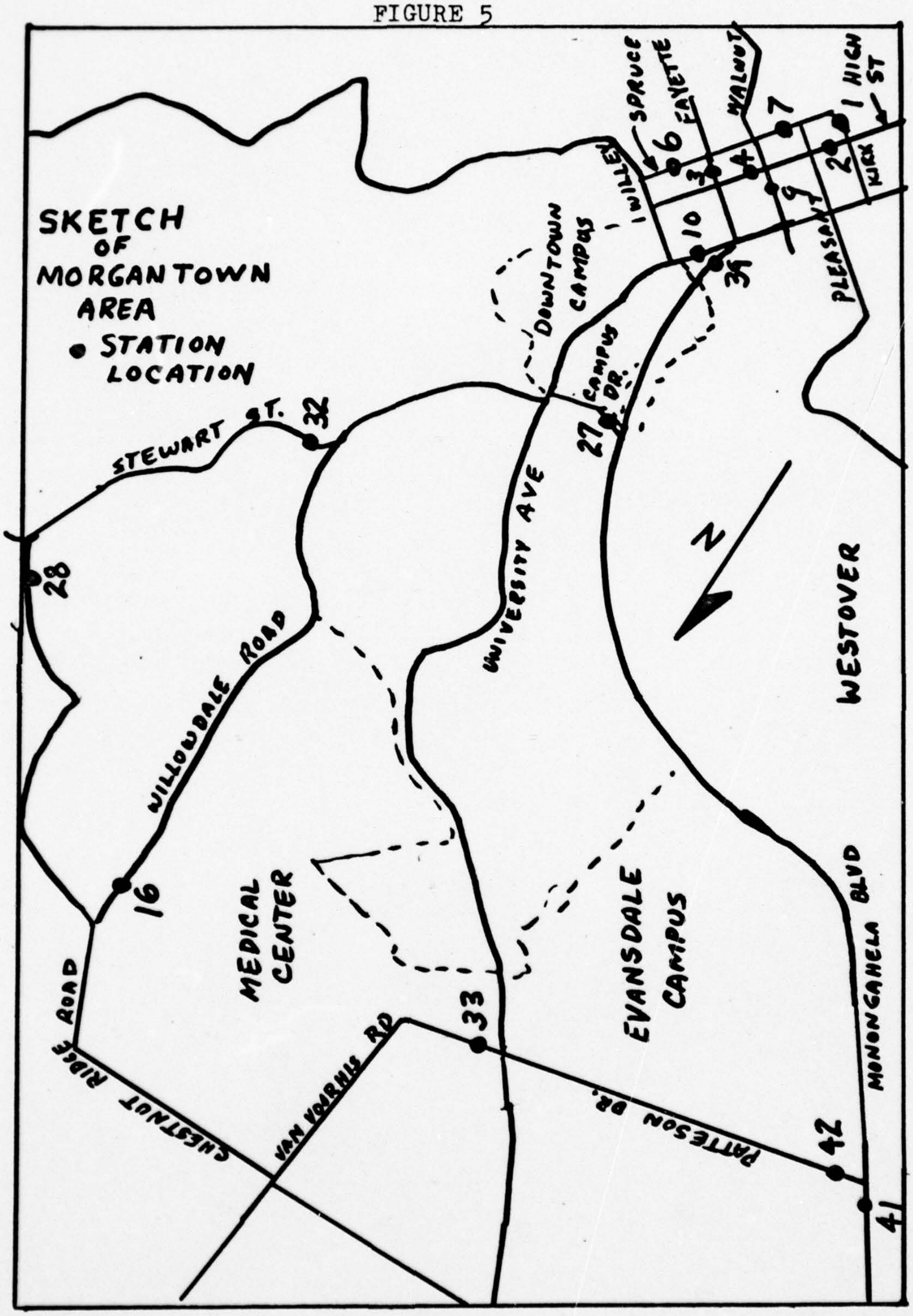
After selecting the links for study, the hourly values of the traffic counts are arranged in a matrix form. That is, they are arranged by link and by succeeding hours. From this, a 24-hour total vehicle count for every link can be obtained.

Then, counts for certain links are removed. The hourly counts extending across every link in the study can be manipulated to form a matrix of a few columns and rows with varying numbers of missing values of hourly counts. This corresponds to pneumatic counters on certain links and aerial photographs taken at specific time intervals. From this reduced matrix, estimates of

vehicle traffic for each link for a total 24-hour period will be made using the guidelines previously mentioned.

Then comparison of the estimates of vehicles of the incomplete matrix is made with the values obtained from the complete matrix of hourly counts. The number and location of hourly counts, the number of fully counted links, and the duration of counts can be changed. One objective would be to obtain an accurate count using the fewest number of links completely counted(pneumatic counters) and the fewest number of hourly counts(aerial photographic counts).

FIGURE 5


SKETCH
OF
MORGANTOWN
AREA
• STATION
LOCATION
STEWART ST.
32
28
WILLOWDALE ROAD
16
RIDGE ROAD
CHESTNUT RIDGE
VAN VOORHIS RD
MEDICAL
CENTER
33
UNIVERSITY AVE
DOWNTOWN
CAMPUS
CAMPUS
DR.
27
EVANSDALE
CAMPUS
PATTESON DR.
42
41
MONONGAHELA BLVD
WESTOVER
N
WILLEY
SPRUCE
FAYETTE
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KIRK
PLEASANT
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34

The Count

The data used was for traffic counts in the Morgantown area on April 20, 1977 as recorded by the West Virginia Department of Highways.

The following list of count stations has the West Virginia DOH station number, the street or highway, and a classification by usage.

Station Number	Street/Highway	Classification
32	Stewart Street	Collector
3	Fayette Street	Collector
10	University Avenue	Collector
16	Willowdale Road	Collector
27	Campus Drive	Collector
1	Kirk Street(one-way)	Arterial
28	Chestnut Ridge Road	Arterial
2	North High Street	Arterial
7	Spruce Street	Arterial
6	Spruce Street	Arterial
9	Walnut Street	Arterial
33	Patteson Drive	Arterial
4	North High Street	Arterial
39	Monongahela Boulevard	Arterial
42	Monongahela Boulevard	Arterial
41	Monongahela Boulevard	Arterial

A cutoff of 5,000 vehicles per day was used as the definition of arterial versus collector. The traffic counts were a 48-hour count at each station. For this study, the 24-hour count for midnight-to-midnight on April 20, 1977 was used as the study input. Sixteen stations were used.

Use of Counts

The traffic flow was summed for each hour segment throughout the day. The hour designation for each vehicle count is the hour at the end of the timespan being counted. For example, the count for hour 6 at Station X is the number of vehicles passing Station X between 5 a.m. and 6 a.m. The hours of the day were numbered sequentially from 1 to 24.

Each station had its hourly counts totaled to produce a total daily count. The entire group of 16 stations with their 24 hours of counts formed a matrix. The counts were considered as base counts for comparisons to the estimated counts.

The West Virginia Department of Highways used the average of the two daily totals of traffic as the Average Daily Traffic(ADT) for a particular station.

In using only a one-day count as representative of daily traffic, variation from the average was expected and encountered. This study was aimed at examining the time variations for one specific day. The assumption is made that the count of vehicles used was a fair and accurate representation of the daily traffic.

By using certain stations' hourly counts as representative of variations by time over the 24-hour period, then other ststions' total vehicle counts for that day

were estimated. This estimation was based on using selected hours of the station counts to be estimated and multiplying these hours by factors drawn from stations selected as indicators of time and frequency variations in traffic.

Description of computer Procedures

To explain the computer program written for this study, an explanation of the mathematics used to obtain a computed count for comparison with an actual count is shown in the following example.

The counts used are for Stations 42 and 4. These counts are shown in Table 1.

Table 9.1 is the table of computed counts using Station 42 as the basis for estimating the counts at the 15 remaining stations.

The 24 hours of the day were divided into 4 six-hour segments. These segments were hours 1 - 6, 7 - 12, 13 - 18, and 19 - 24.

The hours used for each segment to provide counts for a factor of multiplication were the hours of 1, 9, 17, and 20. These hours were chosen to have one hour in each of the 4 six-hour segments. These single hours were called division hours.

The computer program computed an estimated count for Station 4 in the following manner.

For Station 42, the counts for hours 1 through 6 were summed.

$$\begin{array}{r} 203 \\ +104 \\ +\ 39 \\ +\ 23 \\ +\ 31 \\ +118 \\ \hline 518 \end{array} \text{ total vehicles}$$

To obtain a factor for this segment of hourly counts, this total count was divided by the Station 42 count for hour 1, the division hour for that segment.

$$\frac{518}{203} = 2.552, \text{ factor for the first segment}$$

For the remaining segments of counts, a similar procedure was used to obtain factors for each segment.

Hours 7 through 12, the factor is 4.870.

Hours 13 through 18, the factor is 5.792.

Hours 19 through 24, the factor is 4.230.

Since, in a remote sensing look at traffic, the counts for hours 1, 9, 17, and 20 would be known for Station 4 also, the next step in the computer program was to multiply the counts for these hours at Station 4

by the factors obtained from Station 42.

This gave an estimated total count for all six hours in each segment. These total counts for each of the segments were then summed to produce an estimated count for the station for the day.

	Station 4 Counts		Factor		
Hour 1	252	X	2.552	=	643
Hour 9	872	X	4.870	=	4246
Hour 17	1086	X	5.792	=	6290
Hour 20	813	X	4.230	=	3439
			Total		14618

Then the computer compared the computed count of 14618 with the actual count of 14905 for Station 4 and computed the chi-square factor of 5.520.

The percentage difference was computed manually. The computed count differed from the actual count by -1.9%.

Similar procedures were used to obtain estimated counts for the other series of estimates using different stations or hours as basis to calculate the factors for the segments of hours of the day.

Chi-Square Test

Since frequency of vehicle passage is the basis of traffic counting, the initial thought of a test for the "goodness" of the estimated counts led to selection of the chi-square test.

This test is a measure of the discrepancy existing between observed frequencies and expected frequencies. In this study, the counts supplied by the West Virginia DOH served as the absolute or expected frequencies of vehicles counted. The estimated frequency of vehicles for each station calculated by the computer program written for this study would serve as the actual or observed frequency.

Chi-square is given by the formula:

$$\chi^2 = \sum_{j=1}^{k} \frac{(O_j - e_j)^2}{e_j}$$

where O_j is the observed frequency

and e_j is the expected frequency.

If $\chi^2 = 0$, observed and expected frequencies are equal. If $\chi^2 > 0$, then there is a discrepancy between observed and expected frequencies.

The values for χ^2 are based on degrees of freedom. For this estimation, the number of degrees of freedom was equal to k - 1, where k = number of frequencies to be estimated.

After several computer runs, it became obvious the chi-square test was inappropriate because of the large chi-square values being computed. There simply was too

much variation in the counts of the stations to state that one street had the same frequency of traffic as another street. The variations between actual and estimated counts were much more than could be attributed to chance as shown by tables of chi-square values applicable to the degrees of freedom determined by the numbers of estimated counts. Therefore, each street did have a different frequency of traffic for each segment of hours of the day. This difference in frequencies was apparently more than would be applicable to chi-square testing with its assumption of almost normally shaped distribution of expected frequencies. How much difference in frequencies would be determined by how well the estimated counts could be matched to the actual counts.

However, the number produced by chi-square could serve as a relative indicator of the "goodness" of estimation. The chi-square number was independent of size of sample and by being squared, always a positive number. Therefore, this number is listed along with the estimated frequency totals. The number gives a quick way to determine which stations produced the greatest amounts of variation.

Comparisons Made in the Study

For this study the difference between observed and expected frequencies was tabulated by the just-mentioned

chi-square factor and by a percentage comparison of the actual and estimated counts. This percentage comparison is important because traffic count sampling is designed to obtain counts of traffic that are within a specified percentage of actual numbers of vehicles. By listing this percentage difference between actual and estimated counts, it can be ascertained how well the estimating procedure is performing to produce counts for those stations being estimated.

Using the Statistical Analysis System, a correlation matrix between hours of counts and a correlation matrix between the counting stations were calculated. The factor analysis program was also run on the groups of counts by hours and on the group of stations. Using different combinations of hours and/or stations, it can be ascertained if any relationships exist among the counts at the counting stations or among the counts by hour. It can also be seen how strong the correlation is between specific hourly counts for different stations.

Truck Factor

For this study the truck factor adjustment was disregarded. West Virginia DOH applies a truck factor(TF) for certain roadways that is statewide in application. Therefore, any factor applied in the Morgantown area did

not reflect an accurate assessment of the volume of trucks using the streets. The truck factor was applied only to the total daily count. In actual counts, the truck factor cannot be disregarded. For this study, the number of vehicles counted during each hour was not factored in any way. This was because the study was aimed at comparing variations in traffic flows.

An important benefit of aerial photographic studies is an accurate count of the numbers of trucks using the roads and streets. The truck factor obtained from aerial means is a unique and accurate figure to apply for adjustments of the traffic counts in a specific area.

CHAPTER VI

RESULTS OF TESTS

The results of using a computer program to generate estimates of traffic volumes based on patterns of flow are shown in tables contained in the Appendix.

Since this approach has not been studied before, the objectives of the study included finding stations whose flow patterns would serve as reasonable guides to flow patterns of other streets and finding hours of the day in which counts could be used for estimation.

Two approaches were used in dividing the hours of the day into segments which had hourly counts which could define a definite pattern. One method was to divide the day into four six-hour segments. These segments included the hourly counts for hours 1 to 6, 7 to 12, 13 to 18, and 19 to 24.

The second approach was to divide the hours of the day into six segments. These segments included hourly counts for hours 1 to 6, 7 to 9, 10 to 12, 13 to 15, 16 to 18, and 19 to 24. These two approaches were used to test the theory that a day's traffic flow could be broken into segments of flow. By narrowing the segments that included the morning and evening peak hours, those peak hour volumes should have a strong effect upon predictions for the peak hour volume estimates for all

roads. Since a substantial percentage of the daily traffic is concentrated in peak hour flows, it would appear logical to concentrate upon those peak hour counts.

The tests were carried out in the following order:

(a) Four Stations,

(b) Five Stations,

(c) Six Stations, and

(d) Sixteen Stations.

This order refers to the number of stations used in each series of estimations.

For the four-station tests, four stations were chosen that were geographically close. They were 1/2 to 3/4 of a mile apart.

For the five-station tests, five stations were chosen that were in the mid-range of volumes of traffic. This was to minimize the effects of stations having volumes of traffic on the extremes of the range of volumes.

Four of the stations were located in the downtown area. One was located on a major arterial near the Evansdale campus. All had heavy peak hour volumes.

In the six-station tests, stations were chosen with high volumes of traffic. The locations of these stations were widely separated.

For the sixteen-station tests, all of the counting

stations were lumped together with a resulting mixture of volumes and time patterns.

One hourly count in each of the segments of counts had to be used to obtain the factors used for estimation. During the first part of this study, these hours were chosen at random. This was done to study the effects of using different hourly counts in estimating volumes.

In the latter part of the study, a statistical analysis of the hours and stations was introduced. A computation of correlations and a factor analysis were executed for the hourly counts and counts of stations. The results of these are detailed in the section on factor analysis and in Tables 2 & 3 in the Appendix.

Vehicle Counts

Table 1 is a listing of vehicle counts by station and hour. The West Virginia DOH weekday average daily traffic(ADT) is also shown. The count of the station that is used as the base for comparison in this study is also shown. This count is compared to the ADT and percentage difference is noted. The percentage difference ranges from a -3.5% to a +6.4% for individual stations. The last two columns of the table show the sum of the counts for each hour and the ranking by volume of the hours. The table is arranged by the lowest to highest volumes for the stations.

Correlations

In Table 2, the correlations of hourly counts for the day of all stations are shown. These correlations were computed using the Statistical Analysis System program. A perfect correlation is shown by the number 1.00000. The number shown at the intersection of a row and a column shows the correlation between the count of the hour of the row and the count of the hour of the column. This number is called the R value. The closer this number is to 1.00000, the stronger is the correlation between the counts of the two hours.

For example, the correlations shown in the column under Hour 1 are the correlations between the counts for Hour 1 and the counts for all other hours in the day.

There was no strong correlation shown between hourly counts in the early morning and hourly counts throughout the rest of the day. The hourly counts for Hour 4 showed very poor correlation with most other hourly counts for other hours of the day.

For example, the correlations between the counts for Hour 4 and the counts for Hours 12 and 13 were, respectively, 0.55707 and 0.44538. This means that only approximately 20% to 30% of the variation between these hourly counts could be explained as normal deviation from a common factor.

Another feature noted in the correlation analysis

was the high correlation throughout the daytime hours of a particular hour with the hour or two hours immediately preceding or following a particular hour. For example, the correlation of the count for hour 14 with the counts for hours 13 and 15 shows a very high R value. The significance of this may lie in the fact that hourly counts may not be the best way to count traffic. In this study, traffic flows of a particular variation appear to last longer than an hour in time span.

Table 3 shows the correlations between the counts for all 16 stations used in the study. As expected, the correlations between the counts for the stations with the smaller volumes of traffic were not as strong as the correlations between the counts of stations with the larger volumes.

Four Station Tests

Tables 4.1.1 through 4.3.4 show the results of estimation in the counts of four stations. The stations used were stations 28, 16, 27, and 32.

The day was divided into six segments of hours as described earlier.

Tables 4.1.1 through 4.1.4 show the results of using two of the stations as basis for estimating the counts for the remaining two stations. The randomly selected hours used to provide factors for estimation in each

segment of hours were the hours of 2, 9, 10, 13, 17, and 19.

In Table 4.1.1, stations 27 and 32 were used to estimate the counts for stations 28 and 16.

Results: -0.6% difference in total counts
33.973 total chi-square factor

In Table 4.1.2, stations 28 and 32 were used to estimate the counts for stations 16 and 27.

Results: -4.8% difference in total counts
91.512 total chi-square factor

In Table 4.1.3, stations 28 and 16 were used to estimate the counts for stations 27 and 32.

Results: +0.8% difference in total counts
17.996 total chi-square factor

In Table 4.1.4, stations 16 and 32 were used to estimate the counts for stations 28 and 27.

Results: +2.4% difference in total counts
31.560 total chi-square factor

For Tables 4.2.1 through 4.2.4, the randomly selected hours of counts used to provide factors for estimation were the hours 6, 8, 12, 15, 18, and 20. Again two stations were used to provide the basis for estimation of counts for the remaining two stations.

In Table 4.2.1, stations 16 and 27 were used to

estimate the counts for stations 28 and 32.

Results: -1.5% difference in total counts

8.291 total chi-square factor

In Table 4.2.2, stations 28 and 27 were used to estimate the counts for stations 16 and 32.

Results: +1.3% difference in total counts

13.905 total chi-square factor

In Table 4.2.3, stations 27 and 32 were used to estimate the counts for stations 16 and 28.

Results: +1.1% difference in total counts

15.077 total chi-square factor

In Table 4.2.4, stations 28 and 32 were used to estimate the counts for stations 16 and 27.

Results: +1.8% difference in total counts

16.562 total chi-square factor

Comments

A direct comparison between the results of Table 4.1.1 and Table 4.2.3 shows the second series of hours produced better estimates as shown by the chi-square factor.

The same is true for a comparison between the results of Table 4.1.2 and Table 4.2.4. For these stations, the counts for the hours of 6, 8, 12, 15, 18, and 20 produced better results than the counts for the hours of 2, 9, 10, 13, 17, and 19.

Another result to note is the makeup of the

chi-square factor. This factor is a measure of "goodness" of estimation. In all preceding tables, the total chi-square factor had a large part of it composed of the chi-square factor for one station. In other words, the estimate of one station was "good" or of low variation from the true count, while the estimate of the remaining station had an estimate of a much greater variation.

For the next series of tests, the same four stations were used, stations 28, 16, 27, and 32.

Only one station was used to estimate the counts for the remaining three stations.

The hours of the day were divided into six segments to provide six groupings of hourly counts. One hour in each of these segments was chosen to provide the counts for the factors used in estimating. The counts used were the counts of hours 2, 9, 10, 13, 17, and 19.

By using the same four stations but only using one station to estimate the counts for the remaining stations, it can be determined what kind of accuracy loss can be attributed to reducing the basis of estimation from two stations to one station.

In Table 4.3.1, station 28 was used to estimate the counts for stations 16, 27, and 32.

Results: -4.2% difference in total counts

83.129 total chi-square factor

In Table 4.3.2, station 16 was used to estimate the counts for stations 28, 27, and 32.

Results: +9.9% difference in total counts

263.112 total chi-square factor

In Table 4.3.3, station 27 was used to estimate the counts for stations 28, 16, and 32.

Results: +3.9% difference in total counts

86.405 total chi-square factor

In Table 4.3.4, station 32 was used to estimate the counts for stations 28, 16, and 27.

Results: -5.6% difference in total counts

105.342 total chi-square factor

In comparing the results of using two-station estimates and using one station as the estimator, the estimates were better using two stations as basis for the estimated counts. This is partially explained by the fact there were fewer stations to estimate. However, the averaging tendency of combining two stations for a basis for estimation can explain some of the reduction in errors of estimation.

Station 16 seemed to be the worst station both for estimating and for use as a basis of estimation. It is in the same area as station 28. Yet, it does vary considerably from station 28 when both are estimated by other stations.

Station 16 is on a roadway connecting roadways measured by stations 28 and 32. Chestnut Ridge Road (Station 28) and Stewart Street(Station 32) carry traffic to and from centers of attraction, i.e., downtown and the Evansdale Campus. Willowdale Road(Station 16) connects these two roadways.

Therefore, even though these three stations are in close proximity to each other, the roadway connecting two main routes of travel to and from centers of attraction does not appear to be useful in predicting travel on those main routes.

Another aspect of estimation noted in the one-station tests were relationships between stations 28 and 32, and between stations 16 and 27 in predicted counts. According to the percentage differences and chi-square factors, stations 28 and 32 could be presumed to have the same flow patterns. The same holds true for stations 16 and 27. While one station of these two-station groupings predicted the other station of this grouping well, the remaining two stations had a much greater error.

Five Station Tests

In the series of tests using five stations, the thrust of the effort was directed toward testing which combination of hours chosen provided the closest estimates of the true counts of traffic.

The five stations had volumes of counts located near the middle of the range of volumes for all the stations. This was to minimize any effects of stations having very large volumes of traffic or very small volumes of traffic. The stations used in this series of tests were the stations 33, 9, 6, 7, and 2.

The 24 hours of the day were divided into six segments. The segments of hourly counts were the hours of: 1 to 6, 7 to 9, 10 to 12, 13 to 15, 16 to 18, and 19 to 24. This was to have a smaller number of hourly counts clustered about the peak hours.

Four sets of hours were used as division hours. These hourly counts provided factors for estimation for each section of hours of the day. The hourly counts were chosen randomly, but chosen so as to have one hour in each of the six segments of hourly counts throughout the day.

Tables 5.1.1 through 5.1.4 show the results of using stations 33 and 9 combined to produce estimates of counts for stations 6, 7, and 2.

In Table 5.1.1, the division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: +0.8% difference in total count

12.530 total chi-square factor

In Table 5.1.2, the division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: -0.5% difference in total count

32.005 total chi-square factor

In Table 5.1.3, the division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: +4.6% difference in total count

202.891 total chi-square factor

In Table 5.1.4, the division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: +0.7% difference in total count

24.311 total chi-square factor

Tables 5.2.1 through 5.2.4 show the results of using stations 33 and 7 combined to produce estimates of counts for stations 9, 6, and 2.

In Table 5.2.1, the division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: -0.2% difference in total count

8.028 total chi-square factor

In Table 5.2.2, the division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: -0.1% difference in total count
24.193 total chi-square factor

In Table 5.2.3, the division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: +1.6% difference in total count
39.201 total chi-square factor

In Table 5.2.4, the division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: -1.3% difference in total count
58.784 total chi-square factor

Tables 5.3.1 through 5.3.4 show the results of using stations 7 and 2 combined to produce estimates of counts for stations 33, 9, and 6.

In Table 5.3.1, the division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: -1.8% difference in total count
24.864 total chi-square factor

In Table 5.3.2, the division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: +0.2% difference in total count
21.793 total chi-square factor

In Table 5.3.3, the division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: -3.6% difference in total counts

166.151 total chi-square factor

In Table 5.3.4, the division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: -1.8% difference in total count

54.501 total chi-square factor

Tables 5.4.1 and 5.4.2 show the results of using stations 9 and 6 combined to produce estimates of counts for stations 33, 7, and 2.

In Table 5.4.1, the division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: +1.3% difference in total count

20.630 total chi-square factor

In Table 5.4.2, the division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: -0.2% difference in total count

72.966 total chi-square factor

Due to an oversight in running the computer program, estimates using the division hours of 6, 9, 12, 15, 18, and 19; and the hours of 6, 8, 12, 15, 18, and 20 were not made.

Comments

Overall, the first set of division hours, the hours of 2, 9, 10, 13, 17, and 19, gave the best estimations. This means the counts of those division hours were the counts used to calculate factors used for estimation.

In comparing the second and fourth sets of division hours, the hours of 6, 9, 12, 15, 18, and 19; and the hours of 6, 8, 12, 15, 18, and 20, the fourth set of hours gave results showing greater variation from actual counts at the stations. The difference between the two sets of hours was the changing of two of the hours used as division hours. The fourth set of division hours used hours 8 and 20 in place of hours 9 and 19 of the second set of division hours.

This is the ranking of hours by volume:

Hour	Rank
8	13
9	8
20	10
19	9

Therefore, the difference in accuracy between these two sets of division hours appears to be due to the use of higher volume hours as basis for estimation.

Again noted in this series of tests were the distribution of the chi-square factors. This factor is a measure of the "goodness" of the estimate. The greater

the error of the estimated count from the actual count, then the greater the chi-square factor.

In this series, as in the previous series of tests with four stations, the total chi-square factor was made up in large part by the chi-square factor of one station. This one large chi-square factor did not come from the same station in each series. This fact could be an indication that to predict the count at a certain location, there needs to be specific combinations of hours used to estimate the count and specific combinations of other stations to serve as a base for estimation.

Six Station Tests

Six stations were used for the next series of tests. The six stations were stations 9, 28, 33, 39, 41, and 42. The locations of these stations were widely separated. The locations were all on high volume routes. The stations were chosen because of this factor. Variations of a small number of vehicles passing the station should not affect the trends in flow patterns on these routes as much as the same number of vehicles on a lower volume route.

To form a basis for estimation, the tests using six stations were carried out in two phases. First, one station was used to estimate the counts for the remaining five stations. The results are shown in Tables 6.1.1

through 6.5.2.

The second phase combined three stations' counts to form a basis for estimation. Comparisons of accuracy of estimates could be made between the two ways of using base stations for the predicted count. The results of the second phase are shown in Tables 7.1.1 through 7.6.2. The stations used for the basis of estimation were chosen at random.

In Table 6.1.1, station 28 was used to estimate the counts of the remaining five stations. The hours used as division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: -1.3% difference in total count
81.950 total chi-square factor

In Table 6.1.2, station 28 was again used to estimate the counts of the remaining five stations. The hours used as division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: -0.04% difference in total count
98.738 total chi-square factor

In Table 6.2.1, station 33 was used to estimate the counts of the remaining five stations. The hours used as division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: +0.9% difference in total count

82.476 total chi-square factor

In Table 6.2.2, station 33 was again used to estimate the counts of the remaining five stations. The hours used as division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: +0.4% difference in total count

94.862 total chi-square factor

In Table 6.3.1, station 39 was used to estimate the counts for the remaining five stations. The hours used as division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: -0.5% difference in total count

72.716 total chi-square factor

In Table 6.3.2, station 39 was again used to estimate the counts for the remaining five stations. The hours used as division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: -2.0% difference in total count

125.316 total chi-square factor

In Table 6.4.1, station 41 was used to estimate the counts for the remaining five stations. The hours used as division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: -0.8% difference in total count
74.951 total chi-square factor

In Table 6.4.2, station 41 was again used to estimate the counts for the remaining five stations. The hours used as division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: -1.6% difference in total count
119.079 total chi-square factor

In Table 6.5.1, station 42 was used to estimate the counts for the remaining five stations. The hours used for the division hours were the hours of 6, 9, 12, 15, 18, and 19.

Results: -2.4% difference in total count
123.291 total chi-square factor

In Table 6.5.2, station 42 was again used to estimate the counts for the remaining five stations. The hours used as division hours were the hours of 6, 8, 12, 15, 18, and 20.

Results: -1.4% difference in total count
108.424 total chi-square factor

For the first set of division hours, the counts for the hours of 6, 9, 12, 15, 18, and 19 were used. The second set of division hours used the counts for the hours of 6, 8, 12, 15, 18, and 20. These are the same two sets of division hours used in the previous five station tests.

In comparing the results of this series of estimates, a definite conclusion that using hours 9 and 19 for counts for factors gives better results than using the counts for hours 8 and 20 is not possible. The resulting estimates showed no definite pattern as far as one set of counts of division hours being able to provide counts that were closer to the actual counts.

Stations 39 and 41 gave the best results using the first set of division hours; hours 6, 9, 12, 15, 18, and 19.

Stations 28 and 33 gave the best results using the second set of division hours; hours 6, 8, 12, 15, 18, and 20.

One conclusion possible is that station 9 is not compatible with the other stations in this group. It showed the greatest variations in percentage difference from actual count and in the chi-square factor. In the total chi-square factor for the six stations on each estimate, the chi-square factor for station 9 made up the largest part of the total factor.

Therefore, to look at the impact the errors attributed to station 9 has, the estimates are shown below without the estimated count and chi-square factor of station 9.

The first set of division hours are the hours of 6, 9, 12, 15, 18, and 19.

The second set of division hours are the hours of 6, 8, 12, 15, 18, and 20.

Station 28 as estimator:

	Computed Count	Actual Count	% Difference	Chi-Square Factor
First set of division hours	76359	76600	-0.3	9.234
Second set of division hours	77524	76600	+1.2	15.313

Station 33 as estimator:

	Computed Count	Actual Count	% Difference	Chi-Square Factor
First set of division hours	78066	76600	+1.9	36.872
Second set of division hours	77819	76600	+1.6	24.945

Station 39 as estimator:

	Computed Count	Actual Count	% Difference	Chi-Square Factor
First set of division hours	76987	76600	+0.5	10.360
Second set of division hours	75983	76600	-0.8	9.641

Station 41 as estimator:

	Computed Count	Actual Count	% Difference	Chi-Square Factor
First set of division hours	76728	76600	+0.2	9.649
Second set of division hours	76328	76600	-0.4	4.790

Station 42 as estimator:

	Computed Count	Actual Count	% Difference	Chi-Square Factor
First set of division hours	75504	76600	-1.4	24.348
Second set of division hours	76466	76600	-0.2	4.425

With one exception, the results of estimation were better by not using station 9. The chi-square factors were drastically reduced. And most of the percentage differences were reduced.

Station 9 was located on Walnut Street in the downtown area. The other stations were located away from the downtown area. The difference in time variation of traffic flows peculiar to station 9 can be explained by the fact that station 9 had a heavy flow of traffic throughout the day with less pronounced peak hour flows.

Therefore, the patterns of traffic flow for station 9 were different enough to state that for this study, station 9 should have been grouped with stations of like characteristics and not with the other five stations in this series of tests.

Using the same six stations, now three stations will be used as the basis for estimation. The averaging of the three stations should provide a better estimation for the total count.

The 24 hours were divided into six sections. The section hours were hours 1 to 6, 7 to 9, 10 to 12, 13 to 15, 16 to 18, and 19 to 24.

The count for one hour from each section of hours described above was used to form a set of division hours. The counts for these division hours were used to provide factors for estimating the total count for each station.

In Table 7.1.1, stations 9, 28, and 41 were used to estimate the counts for the remaining three stations, The hours used as division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: -0.8% difference in total count
33.649 total chi-square factor

In Table 7.1.2, stations 9, 28, and 41 were again used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: +0.6% difference in total count
12.606 total chi-square factor

In Table 7.2.1, stations 33, 41, and 42 were used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: +1.3% difference in total count

36.390 total chi-square factor

In Table 7.2.2, stations 33, 41, and 42 were again used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: +0.2% difference in total counts

7.580 total chi-square factor

In Table 7.3.1, stations 28, 33, and 39 were used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: +0.2% difference in total counts

9.980 total chi-square factor

In Table 7.3.2, stations 28, 33, and 39 were again used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: -0.04% difference in total counts

12.597 total chi-square factor

In Table 7.4.1, stations 9, 28, and 33 were used to estimate the counts for the three remaining stations. The hours used for division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: +0.9% difference in total counts
21.397 total chi-square factor

In Table 7.4.2, stations 9, 28, and 33 were again used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: +0.1% difference in total counts
12.555 total chi-square factor

In Table 7.5.1, stations 9, 28, and 39 were used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: -1.5% difference in total count
47.294 total chi-square factor

In Table 7.5.2, stations 9, 28, and 39 were again used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: -0.1% difference in total counts
13.825 total chi-square factor

In Table 7.6.1, stations 9, 28, and 42 were used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 3, 8, 11, 14, 17, and 20.

Results: +0.1% difference in total counts
24.674 total chi-square factor

In Table 7.6.2, stations 9, 28, and 42 were again used to estimate the counts for the remaining three stations. The hours used as division hours were the hours of 2, 9, 10, 13, 17, and 19.

Results: -1.3% difference in total counts
27.582 total chi-square factor

Of the 12 estimates of counts, the variation for total vehicle counts was greater than 1% in only three instances. The greatest variation was a minus 1.5%. In the previous ten estimates that used only one station as a basis for estimation, five had variation for total vehicle count greater than 1%. The greatest variation was a minus 2.4%.

Averaging the three stations did produce a better estimate than using only one station as basis for estimation. However, it did not drastically improve the estimate enough to state that using three stations was justified in order to decrease errors. Using only one station as the basis for estimates gave almost the same results.

Station 9 did not seem to bias the estimates as much in this series of tests. Station 33 was the station showing the greatest variations when estimated.

Overall, the second set of division hours, hours 2, 9, 10, 13, 17, and 19, showed the best results in estimation.

Sixteen Station Tests

The next series of tests were for estimating the counts for 16 stations. No means of classification was used. Every station was lumped together with a resulting mixture of volumes and time patterns.

The 24 hours of the day were divided into four 6-hour sections. The section hours were hours 1 to 6, 7 to 12, 13 to 18, and 19 to 24. The count for one hour from each of these sections was selected to provide the factors used in estimating the total counts for the stations.

In the first series of estimates as shown in Tables 8.1 through 8.6, the counts for hours 4, 9, 15, and 20 were selected as division hours to provide factors used in estimation. Only one station was used to estimate the counts for the remaining fifteen stations. In Tables 8.1 through 8.6, the hours are constant that are used for division hours. Different stations chosen at random

throughout the range of volumes were used for estimation.

In Table 8.1, station 32 was the station used for estimation.

Results: +3.0% difference in total counts
285.544 total chi-square factor

In Table 8.2, station 3 was the station used for estimation.

Results: -2.1% difference in total counts
206.144 total chi-square factor

In Table 8.3, station 16 was the station used for estimation.

Results: +5.8% difference in total counts
798.447 total chi-square factor

In Table 8.4, station 2 was the station used for estimation.

Results: -2.5% difference in total counts
301.499 total chi-square factor

In Table 8.5, station 4 was the station used for estimation.

Results: +2.5% difference in total counts
265.272 total chi-square factor

In Table 8.6, station 42 was the station used for estimation.

Results: -0.8% difference in total counts

177.263 total chi-square factor

Station 42 gave the best results in this series of estimations. The high volume of this station allowed variations to be smoother in each of the four divisions of the day. A few vehicles did not have as great an influence on the time pattern of station 42 as they would have had on a location of less volume.

Station 16 produced the worst estimates. As in an earlier series of estimates, the location of station 16 has a definite effect on its time patterns of traffic flows. Station 16 did not reflect the flows of the arterial traffic to and from centers of attractions.

For the next series of estimates for 16 stations, shown in Tables 9.1 through 10.2, one station was used as the estimator and the hours used as division hours to provide estimates were varied. The 24 hours of the day were divided into 4 six-hour segments.

The station used in Tables 9.1 through 9.8 was station 42. The station used in Tables 10.1 and 10.2 was station 16. The hours used as division hours were randomly chosen and are noted with each table.

Using stations 42 and 16 was to follow up the prediction characteristics of these two stations as shown in earlier estimations. Following earlier indications, station 42 should provide small errors in the estimations while station 16 should give large errors in the estimations.

Station 42 Estimates

In Table 9.1, the hours used as division hours were the hours of 1, 9, 17, and 20.

Results: -0.7% difference in total counts
408.571 total chi-square factor

In Table 9.2, the hours used as division hours were the hours of 4, 11, 18, and 21.

Results: +3.0% difference in total counts
354.614 total chi-square factor

In Table 9.3, the hours used as division hours were the hours of 2, 8, 15, and 19.

Results: -2.0% difference in total counts
383.024 total chi-square factor

In Table 9.4, the hours used as division hours were the hours of 3, 12, 13, and 20.

Results: -1.1% difference in total counts
694.593 total chi-square factor

In Table 9.5, the hours used as division hours were the hours of 5, 7, 16, and 24.

Results: -0.5% difference in total counts

2068.607 total chi-square factor

In Table 9.6, the hours used as division hours were the hours of 1, 9, 14, and 23.

Results: +1.7% difference in total counts

422.573 total chi-square factor

In Table 9.7, the hours used as division hours were the hours of 6, 10, 17, and 22.

Results: +6.0% difference in total counts

1129.446 total chi-square factor

In Table 9.8, the hours used as division hours were the hours of 5, 8, 13, and 19.

Results: -5.6% difference in total counts

985.577 total chi-square factor

Station 16 Estimates

In Table 10.1, the hours used as division hours were the hours of 5, 8, 13, and 19.

Results: +4.9% difference in total counts

940.977 total chi-square factor

In Table 10.2, the hours used as division hours were the hours of 1, 9, 17, and 20.

Results of Table 10.2

+1.0% difference in total counts

367.160 total chi-square factor

The best hours for estimation using station 42 seemed to be the groups of hours 1, 9, 17, and 20; and hours 1, 9, 14, and 23. The counts for hours 4, 11, 18, and 21 gave a lower chi-square factor. However, the percentage difference was 3 percent for the total count and one station varied from the actual count by over 10%.

Estimates using the counts for hours 5, 7, 16, and 24 had the lowest percentage difference for the total count. The chi-square factor was over 2000 for the total estimate with several stations being over 10% in variation from the actual counts.

Station 16 was used to see if a prediction made from a station shown to be a bad basis for estimation from a previous series of estimations would produce the same results. The counts for the hours containing the peak hours, hours 1, 9, 17, and 20, gave the best estimation. Total count variation was 1% with only three stations varying from actual counts by more than 10%. Therefore, even by using station 16, the estimations of counts using the counts for these particular hours proved to be fairly accurate.

In comparing the estimations given by using the two

stations, it is evident the results are almost the same. (Tables 9.1 and 10.2, Tables 9.8 and 10.1) Indications concerning station 16 given by earlier estimations were not borne out by this test.

Sixteen Station Tests

Three Stations Used for Estimation

Next, three stations were used as basis for estimation. The counts for three stations were averaged and used to predict the counts for the remaining 13 stations.

The 24 hours of the day were divided into 4 six-hour segments. For this series of estimations, Tables 11.1 through 11.5, the hours of 4, 9, 15, and 20 were used as division hours. These were chosen at random so as to provide one division hour in each six-hour segment.

By using three stations, consistently close estimations should be made for the total counts. The averaging effect of the three stations should provide a time pattern of flows closer to the average flows of all 16 stations. The stations were chosen at random throughout the range of volumes for all 16 stations.

In Table 11.1, stations 33, 27, and 4 were used for estimation.

Results: +0.9% difference in total count
153.529 total chi-square factor

In Table 11.2, stations 28, 2, and 42 were used for estimation.

Results: -1.6% difference in total counts

185.794 total chi-square factor

In Table 11.3, stations 3, 7, and 33 were used for estimation.

Results: -2.2% difference in total counts

229.995 total chi-square factor

In Table 11.4, stations 32, 1, and 28 were used for estimation.

Results: -1.7% difference in total counts

161.903 total chi-square factor

In Table 11.5, stations 3, 10, and 39 were used for estimation.

Results: -2.1% difference in total counts

217.072 total chi-square factor

In this series of estimations, the value of using more than one station to serve as basis for estimation was shown. Total variation was well within 5% for the total counts. Variation on any one station was well within 10% of the actual counts. The chi-square factor was lower as expected. Part of this was due to two less chi-square factors being added to form the total

chi-square factor. But mainly it was due to the use of three stations as a basis for estimation. There were large variations on only one station which would produce a large chi-square factor. This was station 41. It consistently showed the highest chi-square factor. Its location was next to station 42. Yet station 42 showed no large variations when estimated. Therefore, these two stations had very different traffic flow patterns.

Sixteen Station Tests

Eight Stations Used for Estimation

In the next series of estimations, eight stations were used as the basis for estimation of counts. The stations used and hours used as division hours will vary. This series was designed to see if any improvement in accuracy of estimates could be made by using a higher number of stations as basis for estimation.

The stations are arranged in ascending order by volume. In Tables 12.1 through 12.6, the counts for every other station were used as the basis of estimation.

In Tables 13.1 through 13.4, the counts for the four lowest and four highest stations by volume were used as the basis of estimation.

In Tables 14.1 through 14.3, the counts of the eight highest stations by volume were used as the basis for estimation.

In Tables 15.1 through 15.4, the counts of two stations located in the lower range of volumes plus the counts of six stations located in the mid-range of volumes were used as the basis for estimation.

The 24 hours of the day were divided into 4 six-hour segments. The counts for one hour of each of these segments were chosen at random to use as division hours to provide a factor for each segment for use in estimation.

In Tables 12.1 through 12.6, the stations chosen to provide counts used as the basis for estimation were the stations 32, 10, 27, 28, 7, 9, 4, and 41.

In Table 12.1, the hours used as division hours were the hours of 4, 9, 15, and 20.

Results: +1.7% difference in total counts
152.580 total chi-square factor

In Table 12.2, the hours used as division hours were the hours of 1, 9, 17, and 20.

Results: -0.5% difference in total counts
120.352 total chi-square factor

In Table 12.3, the hours used as division hours were the hours of 5, 8, 13, and 19.

Results: +1.5% difference in total counts
295.738 total chi-square factor

In Table 12.4, the hours used as division hours were the hours of 6, 7, 17, and 20.

Results: -0.6% difference in total counts

1006.184 total chi-square factor

In Table 12.5, the hours used as division hours were the hours of 2, 7, 14, and 21.

Results: +1.2% difference in total counts

551.682 total chi-square factor

In Table 12.6, the hours used as division hours were the hours of 6, 9, 14, and 19.

Results: +1.8% difference in total counts

190.363 total chi-square factor

In Tables 13.1 through 13.4, the stations chosen to provide counts used as the basis for estimation were stations 32, 3, 10, 16, 4, 39, 41, and 42.

In Table 13.1, the hours used as division hours were the hours of 1, 9, 17, and 20.

Results: -0.9% difference in total counts

243.799 total chi-square factor

In Table 13.2, the hours used as division hours were the hours of 5, 8, 13, and 19.

Results: -1.6% difference in total counts

147.991 total chi-square factor

In Table 13.3, the hours used as division hours were the hours of 1, 8, 13, and 20.

Results: -0.6% difference in total counts

114.013 total chi-square factor

In Table 13.4, the hours used as division hours were the hours of 6, 9, 14, and 19.

Results: +0.2% difference in total counts

28.836 total chi-square factor

In Tables 14.1 through 14.3, the stations chosen to provide counts used as the basis for estimation were the stations 7, 6, 9, 33, 4, 39, 41, and 42.

In Table 14.1, the hours used as division hours were the hours of 4, 9, 15, and 20.

Results: +0.4% difference in total counts

58.988 total chi-square factor

In Table 14.2, the hours used as division hours were the hours of 6, 9, 14, and 19.

Results: -0.7% difference in total counts

103.055 total chi-square factor

In Table 14.3, the hours used as division hours were the hours of 6, 9, 15, and 19.

Results: +0.3% difference in total counts

42.670 total chi-square factor

In Tables 15.1 through 15.4, the stations chosen to provide counts used as the basis for estimation were the stations 3, 27, 28, 2, 7, 6, 9, and 33.

In Table 15.1, the hours used as division hours were the hours of 4, 9, 15, and 20.

Results: -0.007% difference in total counts
115.591 total chi-square factor

In Table 15.2, the hours used as division hours were the hours of 6, 9, 14, and 19.

Results: +0.5% difference in total counts
197.234 total chi-square factor

In Table 15.3, the hours used as division hours were the hours of 6, 9, 15, and 19.

Results: +2.1% difference in total counts
259.055 total chi-square factor

In Table 15.4, the hours used as division hours were the hours of 5, 8, 13, and 19.

Results: +2.4% difference in total counts
612.429 total chi-square factor

In this series of tests, the best estimates of counts were those using the eight highest volume stations as the basis for estimation. The series using the four lowest volume stations plus the four highest volume stations also gave good results.

In using different hours for hours of division, the groups of hours using the hour 9 seemed to have good estimates. Hour 9 is the morning peak hour.

In using alternate stations as basis for estimation, the counts for the group of hours 1, 9, 17, and 20 gave the best results. This group of hourly counts contained the counts for both morning and evening peak hours of traffic.

In the group of stations using mostly middle-volume stations as basis for estimation, the counts for the hours of 4, 9, 15, and 20 gave the best estimates.

The results of using eight stations as basis for estimation as opposed to using three stations as basis for estimation did not show that much improvement in terms of percentage difference of total counts or in the total chi-square factor.

Using over twice as many stations for basis of estimation did not improve the accuracy of estimation twice as much.

Therefore, more than one station in a grouping of like stations should be used to provide the base for estimation of traffic counts. This study showed that three stations combined gave fairly accurate estimates of counts for the other thirteen stations. It is not believed that more stations produced a commensurate increase in accuracy.

Factor Analysis

The Factor Analysis program of the Statistical Analysis System was used to find if a common factor was present in the counts by hour to explain variations in volumes. The result is a matrix for each hour evaluated. The number 1.00000 shows a perfect correlation of the hourly volume with the volume predicted by using a common factor. If the variations in volume by hour vary from the volumes explained by this common factor, then a progressively lower number is shown in the matrix.

The computer program also has the ability to "rotate" the common factors to explain the most variation possible as shown by the volumes of the hours. Therefore, if the volumes of traffic counts shown by the counts in this study have common factors which can explain most of the variation shown, then the computer program will "rotate" the factors running throughout the counts and calculate the amount of variation that can be explained by that factor.

Using all 16 stations and 24 hours of counts, the Factor Analysis produced the results shown in Table 16. The higher volumes showed the strongest correlation with the first factor. Hour 4 showed the lowest correlations and the program rotated to a common factor along the

variations in counts that occurred during hour 4. During hour 4, the traffic in the area dropped almost to zero, and any vehicle had a more pronounced effect upon the pattern of time variation.

To see how much this one hour of traffic counts, hour 4, can affect the rest of the counts in the estimation efforts, the Factor Analysis program was used on the counts for the odd hours, i.e., hours 1, 3, etc., and then the counts for the even hours, i.e., hours 2, 4, etc. throughout the day. The results are shown in Tables 16.1 and 16.2.

As can be inferred, the counts for hour 4 are the cause of most of the variations in the estimates of the traffic counts. Because of its low volumes, hour 4 does not behave in the same way as other hours in the pattern of traffic flows. One could conclude the counts for hours 2 and 3 behave in much the same way.

Therefore, the very early morning hours, with their low volumes of traffic, should not be used in estimating traffic for day-long periods.

The Factor Analysis program was also used on the counts of the stations to see if common factors were present in their volumes of traffic. All 16 stations were used with all 24 hours of counts.

The results are shown in Table 17. As expected, the higher volume stations showed a higher correlation to the factor found by the computer program. Station 16, which showed itself to be weak in estimation, has a low correlation number.

From the numbers given in this table, one can conclude the stations behaved in approximately the same patterns throughout the day with regard to traffic time patterns.

Summary in Rankings of Stations

Table 18 shows the summation of the four station tests shown in Tables 4.3.1 through 4.3.4. In this series, one station provided the hourly counts used as a basis for prediction of the total counts for the remaining three stations.

As is evident, the ranking given by using the criteria for accuracy in estimation varies closely with the ranking based on correlations from the factor analysis matrix.

Table 19 shows the summation of the sixteen station tests shown in Tables 8.1 through 8.6. The table shows the stations used, their ranking among the six stations from the correlations of the factor analysis, and the rankings among the six stations based upon the accuracy of estimated counts.

The rankings based on the correlations of the factor analysis correspond closely with the rankings based on accuracy of estimation.

Based upon these two observations, there would seem to be a relationship based on correlations shown in factor analysis that could be used when choosing locations for use in estimating counts of traffic. Initial evidence shown in this study points to further use of a factor analysis or statistical analysis of traffic count stations to choose locations that can provide accurate estimates for all roadways in an area.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Conclusions

The hypothesis tested was that variations in traffic flow along selected roadways in an area could be used to predict traffic flows of other roadways in the area. The results of using this method of estimating traffic show the hypothesis to be essentially correct.

The study was concerned with providing estimates of daily traffic based upon different combinations of hours and count locations. The experiment focused on providing indications of suitability in combining certain hours or count locations to get reasonably accurate estimates of counts. Some conclusions on using certain hours and count locations are discussed below.

The very early morning hours with their low percentage of daily traffic gave poor predictions. These hours should not be used to provide factors for estimation.

The afternoon hours carried the greatest volume of traffic. When combined with the morning peak hour, the afternoon hours gave the best predictions.

The peak hours of traffic should definitely be used when determining estimation factors by the method used in this thesis.

The streets used in this study were chosen at random to provide the West Virginia Department of Highways with statistically acceptable estimates of traffic flow. That the estimates obtained in the experiment are very close to the actual counts is very significant. The conclusion reached is that variations by time have a basic pattern extending across all volume classes of roadways.

This conclusion is further supported by the correlations shown between the hourly counts or between count locations. There were very high R values in most instances.

This leads to another conclusion concerning counting locations. Stations that were in close physical proximity to each other seemed to be varying closely in time patterns. This reinforces the theory that routes in different parts of the city behave in distinct patterns.

To predict the total vehicle miles of travel(VMT) of an area, one can draw a conclusion from the differences between total estimated count and actual count. When all the stations' counts were totalled and compared to the total actual count for all those stations, the percentage difference was very small. This averaging tendency would also apply to those roadways grouped together for estimation. By dividing those roadways into roughly equal lengths, the averaging effect of the group of roadways should produce an estimate of VMT that is

reasonably accurate.

Areas for Future Research

This research was an initial attempt to discern traffic flow patterns for use in traffic volume predictions. The traffic counts used were supplied as a part of the West Virginia Department of Highways annual traffic counts. The locations were statistically selected to provide a reasonable estimate of the total vehicle miles of travel(VMT). Therefore, this experiment was limited to locations that were stations in the DOH count. To obtain a more thorough evaluation of the prediction process, an experiment using locations selected by means other than random choice would be appropriate. These locations could be chosen in terms of physical proximity, volumes of traffic, or by functional classification.

Experiments on the variations of traffic by time have been carried out in the past. The hourly count has been the basic unit for counting. Perhaps experiments can be carried out using a greater or lesser time period. Perhaps two or even three hours grouped together would provide a better factor on which to base an estimation.

Since the early morning hours contained such a small percentage of traffic flow, future experiments would be better suited to obtain their traffic counts during the

daylight hours when most traffic occurs. Those experiments should prove that errors caused by variations in traffic in the early morning hours would be minor.

One future experiment of great importance would be to use aerial sensors to obtain traffic counts of an area that has numerous counting stations in it. Counting by aerial means has been shown to be accurate in several experiments. By isolating a specific region, installing traffic counters at locations on the roadways to serve as basis for estimation and comparison, and using an aerial means of counting traffic, the concept advanced in this thesis can be evaluated. It is suggested an area containing several roads of varying volumes be used. In this way, patterns of flow could be discerned for different types of roadways.

Also, by obtaining aerial photographs of an area and obtaining counts of traffic flows for a period of less than one hour duration, the experiment can determine a minimum time needed to provide a 24-hour count within specified accuracy limits.

Counts taken from aerial photos would record the traffic for only a brief timespan. Implicit in using a series of these counts is the assumption these counts represent smoothly varying rates of flow. If in fact the photos captured the flows in a period when the traffic was not varying smoothly but was flowing in spurts,

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then a certain amount of "noise" would be introduced in the pattern of traffic flow. This "noise" in the pattern of flow would introduce errors. Therefore, studies of this nature would need to determine the number of counts needed to reduce to an acceptable level the errors caused by this "noise" on the flow patterns.

In observing the ranking by volume of the hourly counts, the afternoon hours contained the largest amounts of daily traffic. Perhaps this pattern was unique only to this particular area. Perhaps the traffic engineer needs to discern the flow pattern unique to an area before he can use the method of estimation proposed by this thesis. This would be done in order to determine the hours of the day best suited for use in providing the factors used for estimation.

In this experiment, stations were used that were located in the Central Business District(CBD) of Morgantown and at varying distances from the CBD. To determine if there are certain factors, based upon distance from the CBD, that could be used in the estimation process, an experiment using the CBD and rings of distance around the CBD is recommended.

The use of factor analysis in further studies is recommended. Future studies could concentrate on obtaining predictions of traffic counts based on stations showing high correlation with a common factor explaining

the variation of traffic counts throughout the day. Future studies could concentrate on determining if predicted traffic counts accuracies do in fact vary with the selection of "good" hours or stations as shown by factor analysis.

Further studies are recommended in other cities having varied population and topographic characteristics. These studies could investigate relationships among distances traveled, size of population, corridors of travel, etc.

Another possible area of study is the use of factor analysis in the present counting methods. At present, roadways are chosen at random to provide statistically sufficient samples for use in determining VMT for different types of roads. Perhaps factor analysis could provide a basis for choosing fewer roadways to obtain a count that would be as accurate as the present methods.

APPENDIX

Stations refers to the counting stations as numbered by the West Virginia Department of Highways. In Tables 4.1.1 through 15.4, the station numbers listed in the headings are those stations used as basis for estimation in that table.

Division Hours refers to the counts of the hours chosen to provide factors for use in estimating the total count at a counting station. In Tables 4.1.1 through 15.4, the hours listed in the headings are the hours used as division hours.

Table 1

Vehicle Counts by Hour and by Station

Station	32	3	10	16	27	1	28	2
Hours								
1	29	42	27	36	75	88	67	101
2	16	30	25	20	57	32	32	63
3	6	17	15	13	25	14	10	35
4	9	11	2	5	12	11	12	24
5	7	6	1	10	10	11	5	24
6	14	6	13	39	26	16	35	38
7	86	55	57	202	75	122	216	119
8	200	154	142	283	204	347	424	380
9	208	228	231	212	239	388	412	492
10	141	209	187	137	225	426	293	656
11	128	250	170	186	190	387	277	603
12	133	217	194	243	292	396	296	686
13	152	211	234	229	272	308	361	598
14	165	210	186	229	280	375	325	594
15	194	226	255	360	313	389	420	641
16	227	264	294	397	346	333	531	524
17	306	287	336	434	334	408	622	620
18	288	232	300	344	378	370	502	535
19	230	192	173	260	307	322	366	381
20	158	190	211	216	284	370	305	421
21	120	140	154	171	226	216	253	280
22	122	124	201	174	258	185	176	255
23	114	86	83	143	192	154	168	176
24	67	69	66	67	162	111	131	139
Total	3120	3456	3557	4410	4782	5779	6239	8385
DOH Weekday ADT	3232	3434	3475	4453	4679	5611	6214	7998
% Diff.	-3.5	+0.6	+2.4	-1.0	+2.9	+3.0	+0.4	+4.8

Table 1 Continued

Vehicle Counts by Hour and by Station

Station	7	6	9	33	4	39	42	41
Hours								
1	213	144	178	146	252	210	203	245
2	129	91	167	89	179	136	104	113
3	48	53	77	32	82	54	39	48
4	51	35	66	18	52	34	23	25
5	22	23	28	15	34	52	31	52
6	37	41	70	60	77	120	118	152
7	164	209	403	392	300	568	556	641
8	550	454	652	648	697	1085	1104	1097
9	554	491	743	772	872	1145	1266	1026
10	630	625	658	690	881	979	1070	922
11	657	723	678	589	864	1006	1013	1043
12	576	724	677	734	939	1114	1156	1125
13	559	709	647	763	869	1122	1393	1403
14	603	772	666	675	868	1051	1217	1273
15	571	749	661	782	945	1134	1373	1461
16	523	703	767	788	1005	1072	1509	1813
17	599	794	720	770	1086	1147	1436	1680
18	505	626	598	761	1043	1090	1389	1528
19	562	550	600	767	781	1115	1249	1315
20	596	517	547	771	813	1090	1157	1156
21	383	352	439	629	669	855	923	906
22	389	413	451	508	721	704	667	667
23	287	303	333	397	474	474	496	505
24	234	223	278	345	402	364	402	409
Total	9442	10324	11104	12141	14905	17721	19894	20605
DOH Weekday ADT	9184	9702	11017	12189	14566	17472	20114	20201
% Diff.	+2.8	+6.4	+0.8	-0.4	+2.3	+1.4	-1.1	+2.0

Table 1 Continued

Vehicle Count by Hour and by Station

Hours	Sum of Hour Count	Rank by Volume
1	2056	19
2	1283	20
3	568	21
4	390	23
5	331	24
6	862	22
7	4165	17
8	8421	13
9	9279	8
10	8729	12
11	8764	11
12	9502	6
13	9830	5
14	9489	7
15	10474	4
16	11096	2
17	11579	1
18	10489	3
19	9170	9
20	8802	10
21	6716	14
22	6015	15
23	4385	16
24	3469	18

Table 2

Correlation of Hourly Counts

Hours	1	2	3	4	5
Hours					
1	1.00000	0.92131	0.85180	0.76834	0.87149
2	0.92131	1.00000	0.96882	0.91710	0.76995
3	0.85180	0.96882	1.00000	0.92405	0.73211
4	0.76834	0.91710	0.92405	1.00000	0.58681
5	0.87180	0.76995	0.73211	0.58681	1.00000
6	0.80821	0.65919	0.57921	0.40019	0.90945
7	0.76736	0.63939	0.54309	0.39767	0.84243
8	0.86650	0.71555	0.60824	0.48331	0.89422
9	0.87187	0.75654	0.65695	0.51814	0.86096
10	0.92219	0.81059	0.74672	0.61623	0.88105
11	0.93633	0.81793	0.77125	0.63975	0.92610
12	0.90562	0.78032	0.72770	0.55707	0.91811
13	0.86147	0.69280	0.62234	0.44538	0.88732
14	0.90115	0.74537	0.68901	0.52669	0.91455
15	0.86078	0.68420	0.61940	0.43345	0.89565
16	0.81715	0.63363	0.56621	0.37853	0.85199
17	0.84065	0.65441	0.59074	0.40586	0.87559
18	0.83510	0.64841	0.57085	0.36996	0.86401
19	0.86111	0.68626	0.58479	0.42296	0.88442
20	0.89067	0.72545	0.62339	0.45923	0.88733
21	0.86814	0.71962	0.61612	0.43610	0.86905
22	0.92960	0.85671	0.78984	0.60297	0.87771
23	0.93119	0.82961	0.74715	0.58565	0.87057
24	0.93470	0.84674	0.76020	0.60175	0.87057

Table 2 Continued

Correlation of Hourly Counts

Hours	6	7	8	9	10
Hours					
1	0.80821	0.76736	0.86650	0.87187	0.92219
2	0.65919	0.63939	0.71555	0.75654	0.81059
3	0.57921	0.54309	0.60824	0.65695	0.74672
4	0.40019	0.39767	0.48331	0.51814	0.61623
5	0.90945	0.84243	0.89422	0.86096	0.88105
6	1.00000	0.96841	0.96320	0.92181	0.85396
7	0.96841	1.00000	0.96393	0.92599	0.83020
8	0.96320	0.96393	1.00000	0.97916	0.92597
9	0.92181	0.92599	0.97916	1.00000	0.95989
10	0.85396	0.83020	0.92597	0.95989	1.00000

Table 2 Continued--Correlation of Hourly Counts

Hours Hours	6	7	8	9	10
11	0.88040	0.84611	0.93150	0.94076	0.98426
12	0.90894	0.87501	0.94463	0.96091	0.98653
13	0.95105	0.91844	0.96467	0.96095	0.94726
14	0.93237	0.89563	0.95621	0.95185	0.96555
15	0.95935	0.92178	0.96279	0.95111	0.93909
16	0.96842	0.92984	0.93842	0.90929	0.86475
17	0.96403	0.91986	0.94848	0.92244	0.89303
18	0.96412	0.91722	0.95003	0.93580	0.89556
19	0.96814	0.95212	0.98456	0.96508	0.91759
20	0.94227	0.92410	0.97889	0.97696	0.95052
21	0.95310	0.94064	0.97615	0.97848	0.92931
22	0.88991	0.86108	0.91507	0.93925	0.93273
23	0.91192	0.90198	0.94305	0.95006	0.93349
24	0.88261	0.87357	0.91922	0.94090	0.92968

Table 2 Continued--Correlation of Hourly Counts

Hours Hours	11	12	13	14	15
1	0.92219	0.90562	0.86147	0.90115	0.86078
2	0.81793	0.78032	0.69280	0.74537	0.68420
3	0.77125	0.72770	0.62234	0.68901	0.56621
4	0.63975	0.55707	0.44538	0.52669	0.43345
5	0.92610	0.91811	0.88732	0.91455	0.89565
6	0.88040	0.90894	0.95105	0.93237	0.95935
7	0.84611	0.87501	0.91844	0.89563	0.92178
8	0.93150	0.94463	0.96467	0.95621	0.96279
9	0.94076	0.96091	0.96095	0.95185	0.95111
10	0.98426	0.98653	0.94726	0.96555	0.93909
11	1.00000	0.98616	0.95537	0.98133	0.95162
12	0.98616	1.00000	0.97478	0.98717	0.97318
13	0.95537	0.97478	1.00000	0.99117	0.99647
14	0.98133	0.98717	0.99117	1.00000	0.98982
15	0.95162	0.97318	0.99647	0.98982	1.00000
16	0.88983	0.91157	0.97084	0.95176	0.97733
17	0.91763	0.93443	0.97813	0.96660	0.98661
18	0.90471	0.93522	0.97855	0.96000	0.98464
19	0.92582	0.94796	0.98319	0.96932	0.98073
20	0.94711	0.96752	0.97973	0.97207	0.97550
21	0.92165	0.95328	0.97305	0.95609	0.96947
22	0.93098	0.94818	0.92297	0.93189	0.92146
23	0.93187	0.95063	0.94015	0.94746	0.94091
24	0.91700	0.93656	0.92405	0.92909	0.91996

Table 2 Continued--Correlation of Hourly Counts

Hours Hours	16	17	18	19	20
1	0.81715	0.84065	0.83510	0.86111	0.89067
2	0.63363	0.65441	0.64841	0.68626	0.72545
3	0.56621	0.59074	0.57058	0.58479	0.62339
4	0.37853	0.40586	0.36996	0.42296	0.45923
5	0.85199	0.87559	0.86401	0.88442	0.88733
6	0.96842	0.96403	0.96412	0.96814	0.94227
7	0.92984	0.91986	0.91722	0.95212	0.92410
8	0.93842	0.94848	0.95003	0.98456	0.97899
9	0.90929	0.92244	0.93580	0.96508	0.97696
10	0.86475	0.89303	0.89556	0.91759	0.95052
11	0.88983	0.91763	0.90471	0.92582	0.94711
12	0.91157	0.93443	0.93522	0.94796	0.96752
13	0.97084	0.97813	0.97855	0.98319	0.97973
14	0.95176	0.96660	0.96000	0.96932	0.97207
15	0.97733	0.98661	0.98464	0.98073	0.97550
16	1.00000	0.99201	0.98722	0.96646	0.93943
17	0.99201	1.00000	0.99180	0.96823	0.94923
18	0.98722	0.99180	1.00000	0.97725	0.96319
19	0.96646	0.96823	0.97725	1.00000	0.99016
20	0.93943	0.94923	0.96319	0.99016	1.00000
21	0.94597	0.95090	0.97012	0.98947	0.99296
22	0.87915	0.89695	0.91364	0.92734	0.94993
23	0.90922	0.92057	0.93306	0.95525	0.96405
24	0.89204	0.89882	0.91667	0.93613	0.95117

Table 2 Continued--Correlation of Hourly Counts

Hours Hours	21	22	23	24
1	0.86814	0.92960	0.93119	0.93470
2	0.71962	0.85671	0.82961	0.84674
3	0.61612	0.78984	0.74715	0.76020
4	0.43610	0.60297	0.58565	0.60175
5	0.86905	0.87771	0.87057	0.83773
6	0.95310	0.88991	0.91192	0.88261
7	0.94064	0.86108	0.90198	0.87357
8	0.97615	0.91507	0.94305	0.91922
9	0.97848	0.93925	0.95006	0.94090
10	0.92931	0.93273	0.93349	0.92968
11	0.92165	0.93098	0.93187	0.91700
12	0.95328	0.94818	0.95063	0.93656

Table 2 Continued--Correlation of Hourly Counts

Hours / Hours	21	22	23	24
13	0.97305	0.92297	0.94015	0.92405
14	0.95609	0.93189	0.94746	0.92909
15	0.96947	0.92146	0.94091	0.91996
16	0.94597	0.87915	0.90922	0.89204
17	0.95090	0.89695	0.92057	0.89882
18	0.97012	0.91364	0.93306	0.91667
19	0.98947	0.92734	0.95525	0.93613
20	0.99296	0.94993	0.96405	0.95117
21	1.00000	0.95566	0.96944	0.95913
22	0.95566	1.00000	0.98397	0.97943
23	0.96944	0.98397	1.00000	0.99229
24	0.95913	0.97943	0.99229	1.00000

Table 3--Correlation of Stations

Stations / Stations	32	3	10	16	27
32	1.00000	0.89492	0.92790	0.94072	0.91657
3	0.89492	1.00000	0.95019	0.87254	0.91442
10	0.92790	0.95019	1.00000	0.91390	0.94954
16	0.94072	0.87254	0.91390	1.00000	0.88646
27	0.91657	0.91442	0.94954	0.88646	1.00000
1	0.86231	0.96305	0.88692	0.82063	0.87918
28	0.97434	0.92102	0.93693	0.96649	0.89288
2	0.79006	0.95722	0.88008	0.78712	0.85122
7	0.83160	0.95407	0.86948	0.78460	0.88308
6	0.83911	0.97046	0.91135	0.85283	0.90415
9	0.87765	0.96290	0.90203	0.87011	0.88746
33	0.90108	0.94241	0.92307	0.87678	0.94585
4	0.90762	0.98109	0.96476	0.88096	0.96178
39	0.89549	0.95168	0.90965	0.87497	0.91605
42	0.92573	0.96525	0.94700	0.91600	0.93941
41	0.93395	0.94795	0.94819	0.95619	0.93729

Table 3 Continued--Correlation of Stations

Stations / Stations	1	28	2	7	6
32	0.86231	0.97434	0.79006	0.83160	0.83911
3	0.96305	0.92102	0.95722	0.95407	0.97046
10	0.88692	0.93693	0.88008	0.86948	0.91135
16	0.82063	0.96649	0.78712	0.78460	0.85283
27	0.87918	0.89288	0.85122	0.88308	0.90415
1	1.00000	0.88095	0.96264	0.98205	0.94892
28	0.88095	1.00000	0.83402	0.84424	0.87064
2	0.96264	0.83402	1.00000	0.94523	0.97621
7	0.98205	0.84424	0.94523	1.00000	0.95117
6	0.94892	0.87064	0.97621	0.95117	1.00000
9	0.96476	0.91467	0.93236	0.95879	0.94642
33	0.94925	0.91237	0.89962	0.94627	0.92208
4	0.96002	0.91629	0.94446	0.95663	0.96511
39	0.96852	0.91328	0.92118	0.96376	0.93590
42	0.94747	0.95213	0.92119	0.93498	0.94438
41	0.90013	0.96493	0.88435	0.88707	0.93312

Table 3 Continued--Correlation of Stations

Stations / Stations	9	33	4	39
32	0.87765	0.90108	0.90762	0.89549
3	0.96290	0.94241	0.98109	0.95168
10	0.90203	0.92307	0.96476	0.90965
16	0.87011	0.87678	0.88096	0.87497
27	0.88746	0.94585	0.96178	0.91605
1	0.96476	0.94925	0.96002	0.96852
28	0.91467	0.91237	0.91629	0.91328
2	0.93236	0.89962	0.94446	0.92118
7	0.95879	0.94627	0.95663	0.96376
6	0.94624	0.92208	0.96511	0.93590
9	1.00000	0.96435	0.96190	0.97664
33	0.96435	1.00000	0.96820	0.98904
4	0.96190	0.96820	1.00000	0.96370
39	0.97664	0.98904	0.96370	1.00000
42	0.96618	0.98190	0.96917	0.98254
41	0.93139	0.94606	0.94709	0.94355

Table 3 Continued--Correlation of Stations

Stations Stations	42	41
32	0.92573	0.93395
3	0.96525	0.94795
10	0.94700	0.94819
16	0.91600	0.95619
27	0.93941	0.93729
1	0.94747	0.90013
28	0.95213	0.96493
2	0.92119	0.88435
7	0.93498	0.88707
6	0.94438	0.93312
9	0.96618	0.93139
33	0.98190	0.94606
4	0.96917	0.94709
39	0.98254	0.94355
42	1.00000	0.98275
41	0.98275	1.00000

Table 4.1.1

Stations 27 & 32

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6470	6239	+3.7	8.578
16	4075	4410	-7.5	25.395
27	4782	4782	0	0
32	3120	3120	0	0
Total	18447	18551	-0.6	33.973

Table 4.1.2 Stations 28 & 32

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6239	6239	0	0
16	3874	4410	-12.2	65.243
27	4428	4782	-7.4	26.268
32	3120	3120	0	0
Total	17661	18551	-4.8	91.512

Table 4.1.3 Stations 28 & 16

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6239	6239	0	0
16	4410	4410	0	0
27	4704	4782	-1.6	1.263
32	3348	3120	+7.3	16.733
Total	18701	18551	+0.8	17.996

Table 4.1.4 Stations 16 & 32

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6683	6239	+7.1	31.553
16	4410	4410	0	0
27	4788	4782	+0.1	0.007
32	3120	3120	0	0
Total	19001	18551	+2.4	31.560

Table 4.2.1 Stations 16 & 27

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6042	6239	-3.2	6.205
16	4410	4410	0	0
27	4782	4782	0	0
32	3039	3120	-2.6	2.087
Total	18237	18551	-1.5	8.291

Table 4.2.2 Stations 28 & 27

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6239	6239	0	0
16	4657	4410	+5.6	13.858
27	4782	4782	0	0
32	3108	3120	-0.4	0.046
Total	18786	18551	+1.3	13.905

Table 4.2.3 Stations 27 & 32

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6187	6239	-0.8	0.440
16	4664	4410	+5.8	14.638
27	4782	4782	0	0
32	3120	3120	0	0
Total	18753	18551	+1.1	15.077

Table 4.2.4 Stations 28 & 32

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6239	6239	0	0
16	4669	4410	+5.9	15.240
27	4862	4782	+1.7	1.322
32	3120	3120	0	0
Total	18890	18551	+1.8	16.562

Table 4.3.1 Station 28

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6239	6239	0	0
16	3897	4410	-11.6	59.662
27	4458	4782	-6.8	22.012
32	3187	3120	+2.1	1.455
Total	17781	18551	-4.2	83.129

Table 4.3.2 Station 16

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	7187	6239	+15.2	143.944
16	4410	4410	0	0
27	5159	4782	+7.9	29.740
32	3648	3120	+16.9	89.428
Total	20404	18551	+9.9	263.112

Table 4.3.3 Station 27

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6751	6239	+8.2	41.961
16	4275	4410	-3.1	4.124
27	4782	4782	0	0
32	3475	3120	+11.4	40.320
Total	19283	18551	+3.9	86.405

Table 4.3.4 Station 32

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
28	6149	6239	-1.4	1.302
16	3846	4410	-12.8	72.025
27	4391	4782	-8.2	32.015
32	3120	3120	0	0
Total	17506	18551	-5.6	105.342

Table 5.1.1 Stations 33 & 9

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	11104	11104	0	0
6	10269	10324	-0.5	0.295
7	9605	9442	+1.7	2.814
2	8666	8385	+3.4	9.421
Total	51785	51396	+0.8	12.530

Table 5.1.2 Stations 33 & 9

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	11104	11104	0	0
6	10180	10324	-1.4	2.012
7	9022	9442	-4.5	18.650
2	8693	8385	+3.7	11.342
Total	51140	51396	-0.5	32.005

Table 5.1.3 Stations 33 & 9

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	11104	11104	0	0
6	11158	10324	+8.1	67.442
7	10431	9442	+10.5	103.491
2	8903	8385	+6.2	31.958
Total	53737	51396	+4.6	202.891

Table 5.1.4 Stations 33 & 9

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	11104	11104	0	0
6	10209	10324	-1.1	1.270
7	9479	9442	+0.4	0.143
2	8823	8385	+5.2	22.897
Total	51756	51396	+0.7	24.311

Table 5.2.1 Stations 33 & 7

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	10976	11104	-1.2	1.477
6	10172	10324	-1.5	2.244
7	9442	9442	0	0
2	8575	8385	+2.3	4.307
Total	51306	51396	-0.2	8.028

Table 5.2.2 Stations 33 & 7

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	10794	11104	-2.8	8.663
6	10214	10324	-1.1	1.170
7	9442	9442	0	0
2	8732	8385	+4.1	14.360
Total	51323	51396	-0.1	24.193

Table 5.2.3 Stations 33 & 7

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	11096	11104	-0.1	0.005
6	10882	10324	+5.4	30.139
7	9442	9442	0	0
2	8661	8385	+3.3	9.057
Total	52222	51396	+1.6	39.201

Table 5.2.4 Stations 33 & 7

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12141	12141	0	0
9	10443	11104	-5.9	39.331
6	10032	10324	-2.8	8.279
7	9442	9442	0	0
2	8691	8385	+3.6	11.174
Total	50749	51396	-1.3	58.784

Table 5.3.1 Stations 7 & 2

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	11851	12141	-2.4	6.905
9	10793	11104	-2.8	8.698
6	10015	10324	-3.0	9.262
7	9442	9442	0	0
2	8385	8385	0	0
Total	50486	51396	-1.8	24.864

Table 5.3.2 Stations 7 & 2

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12567	12141	+3.5	14.961
9	10836	11104	+2.4	6.446
6	10261	10324	-0.6	0.386
7	9442	9442	0	0
2	8385	8385	0	0
Total	51491	51396	+0.2	21.793

Table 5.3.3 Stations 7 & 2

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	10866	12141	-10.5	133.797
9	10505	11104	-5.4	32.352
6	10328	10324	+0.01	0.002
7	9442	9442	0	0
2	8385	8385	0	0
Total	49526	51396	-3.6	166.151

Table 5.3.4 Stations 7 & 2

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12247	12141	+0.9	0.930
9	10412	11104	-6.2	43.152
6	9996	10324	-3.2	10.420
7	9442	9442	0	0
2	8385	8385	0	0
Total	50482	51396	-1.8	54.501

Table 5.4.1 Stations 9 & 6

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	12224	12141	+0.7	0.565
9	11104	11104	0	0
6	10324	10324	0	0
7	9662	9442	+2.3	5.126
2	8739	8385	+4.2	14.940
Total	52053	51396	+1.3	20.630

Table 5.4.2 Stations 9 & 6

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
33	11427	12141	-5.9	41.940
9	11104	11104	0	0
6	10324	10324	0	0
7	9975	9442	+5.6	30.060
2	8475	8385	+1.1	0.965
Total	51305	51396	-0.2	72.966

Table 6.1.1 Station 28

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10205	11104	-8.1	72.716
28	6239	6239	0	0
33	11895	12141	-2.0	5.001
39	17577	17721	-0.8	1.178
41	20522	20605	-0.4	0.337
42	20126	19894	+1.2	2.717
Total	86564	87704	-1.3	81.950

Table 6.1.2 Station 28

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10142	11104	-8.7	83.425
28	6239	6239	0	0
33	12136	12141	-0.04	0.002
39	18083	17721	+2.0	7.381
41	20900	20605	+1.4	4.213
42	20166	19894	+1.4	3.716
Total	87666	87704	-0.04	98.738

Table 6.2.1 Station 33

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10392	11104	-6.4	45.604
28	6341	6239	+1.6	1.681
33	12141	12141	0	0
39	17971	17721	+1.4	3.522
41	21068	20605	+2.2	10.391
42	20545	19894	+3.3	21.278
Total	88458	87704	+0.9	82.476

Table 6.2.2 Station 33

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10223	11104	-7.9	69.917
28	6281	6239	+0.7	0.286
33	12141	12141	0	0
39	18181	17721	+2.6	11.928
41	20992	20605	+1.9	7.269
42	20224	29894	+1.7	5.462
Total	88042	87704	+0.4	94.862

Table 6.3.1 Station 39

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10272	11104	-7.5	62.356
28	6266	6239	+0.4	0.120
33	11988	12141	-1.3	1.933
39	17721	17721	0	0
41	20731	20605	+0.6	0.772
42	20281	19894	+1.9	7.534
Total	87259	87704	-0.5	72.716

Table 6.3.2 Station 39

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	9971	11104	-10.2	115.675
28	6130	6239	-1.7	1.901
33	11862	12141	-2.3	6.419
39	17721	17721	0	0
41	20506	20605	-0.5	0.475
42	19764	19894	-0.7	0.846
Total	85954	87704	-2.0	125.316

Table 6.4.1 Station 41

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10252	11104	-7.7	65.302
28	6288	6239	+0.8	0.384
33	11953	12141	-1.5	2.903
39	17642	17721	-0.4	0.349
41	20605	20605	0	0
42	20240	19894	+1.7	6.013
Total	86980	87704	-0.8	74.951

Table 6.4.2 Station 41

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	9977	11104	-10.1	114.289
28	6175	6239	-1.0	0.667
33	11921	12141	-1.8	3.981
39	17763	17721	+0.2	0.098
41	20605	20605	0	0
42	19864	19894	-0.2	0.045
Total	86305	87704	-1.6	119.079

Table 6.5.1 Station 42

Hours 6, 9, 12, 15, 18, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10056	11104	-9.4	98.943
28	6154	6239	-1.4	1.156
33	11753	12141	-3.2	12.423
39	17354	17721	-2.1	7.596
41	20349	20605	-1.2	3.173
42	19894	19894	0	0
Total	85560	87704	-2.4	123.291

Table 6.5.2 Station 42

Hours 6, 8, 12, 15, 18, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	10029	11104	-9.7	103.999
28	6182	6239	-0.9	0.528
33	11942	12141	-1.6	3.271
39	17825	17721	+0.6	0.611
41	20623	20605	+0.1	0.015
42	19894	19894	0	0
Total	86495	87704	-1.4	108.424

Table 7.1.1 Stations 9, 28, & 41

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	11603	12141	-4.4	23.847
39	17925	17721	+1.2	2.349
41	20605	20605	0	0
42	19509	19894	-1.9	7.453
Total	86985	87704	-0.8	33.649

Table 7.1.2 Stations 9, 28, & 41

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	12125	12141	-0.1	0.022
39	17755	17721	+0.2	0.066
41	20605	20605	0	0
42	20393	19894	+2.5	12.517
Total	88221	87704	+0.6	12.606

Table 7.2.1 Stations 33, 41, & 42

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11526	11104	+3.8	16.070
28	6360	6239	+1.9	2.340
33	12141	12141	0	0
39	18285	17721	+3.2	17.980
41	20605	20605	0	0
42	19894	19894	0	0
Total	88811	87704	+1.3	36.390

Table 7.2.2 Stations 33, 41, & 42

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11124	11104	+0.2	0.037
28	6454	6239	+3.4	7.384
33	12141	12141	0	0
39	17668	17721	-0.3	0.158
41	20605	20605	0	0
42	19894	19894	0	0
Total	87886	87704	+0.2	7.580

Table 7.3.1 Stations 28, 33, & 39

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11378	11104	+2.5	6.765
28	6239	6239	0	0
33	12141	12141	0	0
39	17721	17721	0	0
41	20736	20605	+0.6	0.834
42	19676	19894	-1.1	2.382
Total	87891	87704	+0.2	9.980

Table 7.3.2 Stations 28, 33, & 39

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11033	11104	-0.6	0.451
28	6239	6239	0	0
33	12141	12141	0	0
39	17721	17721	0	0
41	20271	20605	-1.6	5.425
42	20260	19894	+1.8	6.720
Total	87665	87704	-0.04	12.597

Table 7.4.1 Stations 9, 28, & 33

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	12141	12141	0	0
39	18271	17721	+3.1	17.048
41	20903	20605	+1.4	4.320
42	19870	19894	-0.1	0.029
Total	88528	87704	+0.9	21.397

Table 7.4.2 Stations 9, 28, & 33

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	12141	12141	0	0
39	17662	17721	-0.3	0.197
41	20347	20605	-1.3	3.226
42	20320	19894	+2.1	9.132
Total	87813	87704	+0.1	12.555

Table 7.5.1 Stations 9, 28, & 39

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	11522	12141	-5.1	31.566
39	17721	17721	0	0
41	20395	20605	-1.0	2.135
42	19374	19894	-2.6	13.592
Total	86355	87704	-1.5	47.294

Table 7.5.2 Stations 9, 28, & 39

Hours 2, 9, 10, 13, 17, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	12049	12141	-0.8	0.700
39	17721	17721	0	0
41	20262	20605	-1.7	5.712
42	20278	19894	+1.9	7.414
Total	87653	87704	-0.1	13.825

Table 7.6.1 Stations 9, 28, & 42

Hours 3, 8, 11, 14, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	11698	12141	-3.6	16.188
39	18091	17721	+2.1	7.721
41	20730	20605	+0.6	0.764
42	19894	19894	0	0
Total	87756	87704	+0.1	24.674

Table 7.6.2 Stations 9, 28, & 42

Hours 2, 9, 10, 13, 17, & 19

Stations	Computed Count	Actual Count	% Difference	Chi-Square Factor
9	11104	11104	0	0
28	6239	6239	0	0
33	11881	12141	-2.1	5.582
39	17398	17721	-1.8	5.882
41	20029	20605	-2.8	16.118
42	19894	19894	0	0
Total	86545	87704	-1.3	27.582

Table 8.1 Station 32

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3608	3608	+4.4	6.696
10	3847	3557	+8.2	23.635
16	4539	4410	+2.9	3.755
27	4744	4782	-0.8	0.297
1	6340	5779	+9.7	54.542
28	6332	6239	+1.5	1.387
2	8897	8385	+6.1	31.315

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Table 8.1 Continued

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
7	9825	9442	+4.1	15.548
6	10226	10324	-0.9	0.923
9	11141	11104	+0.3	0.121
33	12814	12141	+5.5	37.328
4	14886	14905	-0.1	0.025
39	18619	17721	+5.1	45.525
42	21026	19894	+5.7	64.447
41	20610	20605	+0.02	0.001
Total	160574	155864	+3.0	285.544

Table 8.2 Station 3

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3001	3120	-3.8	4.568
3	3456	3456	0	0
10	3651	3557	+2.6	2.486
16	4274	4410	-3.1	4.176
27	4467	4782	-3.1	20.796
1	6027	5779	+4.3	10.665
28	6077	6239	-2.6	4.221
2	8477	8385	+1.1	1.006
7	9349	9442	-1.0	0.911
6	9672	10324	-6.3	41.173
9	10787	11104	-2.9	9.022
33	12150	12141	+0.1	0.007
4	14193	14905	-4.8	34.008
39	17706	17721	-0.1	0.013
42	19979	19894	+0.4	0.367
41	19381	20605	-5.9	72.725
Total	152647	155864	-2.1	206.144

Table 8.3 Station 16

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3289	3120	+5.4	9.125
3	3787	3456	+9.6	31.698
10	3844	3557	+8.1	23.195
16	4410	4410	0	0
27	4807	4782	+0.5	0.135
1	6502	5779	+12.5	90.387
28	6531	6239	+4.7	13.637
2	9080	8385	+8.3	57.548
7	10561	9442	+11.9	132.613
6	10400	10324	+0.7	0.566
9	12320	11104	+10.9	133.236
33	13051	12141	+7.5	68.260
4	15586	14905	+4.6	31.148
39	19138	17721	+8.0	113.380
42	21232	19894	+6.7	89.943
41	20333	20605	-1.3	3.579
Total	164871	155864	+5.8	798.447

Table 8.4 Station 2

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3031	3120	-2.9	2.538
3	3475	3456	+0.5	0.105
10	3627	3557	+2.0	1.391
16	4144	4410	-6.0	15.987
27	4398	4782	-8.0	30.828
1	6029	5779	+4.3	10.831
28	6099	6239	-2.2	3.138
2	8385	8385	0	0
7	9379	9442	-0.7	0.423
6	9478	10324	-8.2	69.313
9	10986	11104	-1.1	1.263
33	12131	12141	-0.1	0.009
4	14189	14905	-4.8	34.401
39	17727	17721	+0.03	0.002
42	19891	19894	-0.02	0.001
41	18960	20605	-8.0	131.271
Total	151929	155864	-2.5	301.499

Table 8.5 Station 4

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3147	3120	+0.9	0.237
3	3626	3456	+4.9	8.409
10	3803	3557	+6.9	17.057
16	4413	4410	+0.1	0.002
27	4679	4782	-2.2	2.234
1	6320	5779	+9.4	50.585
28	6340	6239	+1.6	1.640
2	8825	8385	+5.2	23.064
7	9900	9442	+4.9	22.172
6	10083	10324	-2.3	5.625
9	11403	11104	+2.7	8.032
33	12738	12141	+4.9	29.382
4	14905	14905	0	0
39	18575	17721	+4.8	41.134
42	20853	19894	+4.8	46.189
41	20162	20605	-2.1	9.511
Total	159772	155864	+2.5	265.272

Table 8.6 Station 42

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3059	3120	-1.9	1.190
3	3531	3456	+2.2	1.615
10	3607	3557	+1.4	0.706
16	4239	4410	-3.9	6.604
27	4531	4782	-5.2	13.132
1	6059	5779	+4.8	13.529
28	6111	6239	-2.1	2.632
2	8600	8385	+2.6	5.516
7	9826	9442	+4.1	15.640
6	9903	10324	-4.1	17.150
9	11422	11104	+2.9	9.129
33	12163	12141	+0.2	0.040
4	14581	14905	-2.2	7.054
39	17821	17721	+0.6	0.568
42	19894	19894	0	0
41	19299	20605	-6.3	82.759
Total	154646	155864	-0.8	177.263

Table 9.1 Station 42

Hours 1, 9, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3528	3120	+13.1	53.223
3	3683	3456	+6.6	14.960
10	4032	3557	+13.4	63.522
16	4552	4410	+3.2	4.542
27	4491	4782	-6.1	17.711
1	6042	5779	+4.6	11.977
28	7070	6239	+13.3	110.650
2	8025	8385	-4.3	15.431
7	9232	9442	-2.2	4.688
6	9544	10324	-7.6	58.933
9	10556	11104	-4.9	27.025
33	11853	12141	-2.4	6.838
4	14618	14905	-1.9	5.520
39	17365	17721	-2.0	7.136
42	19894	19894	0	0
41	20241	20605	-1.8	6.416
Total	154726	155864	-0.7	408.571

Table 9.2 Station 42

Hours 4, 11, 18, & 21

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3342	3120	+7.1	15.858
3	3901	3456	+12.9	57.219
10	3693	3557	+3.8	5.163
16	4211	4410	-4.5	8.975
27	4888	4782	+2.2	2.361
1	5964	5779	+3.2	5.905
28	6303	6239	+1.0	0.664
2	8898	8385	+6.1	31.434
7	10202	9442	+8.0	61.112
6	10803	10324	+4.6	22.232
9	11521	11104	+3.8	15.663
33	11882	12141	-2.1	5.534
4	16222	14905	+8.8	116.330
39	17948	17721	+1.3	2.914
42	19894	19894	0	0
41	20864	20605	+1.3	3.250
Total	160536	155864	+3.0	354.614

Table 9.3 Station 42

Hours 2, 8, 15, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3273	3120	+4.9	7.495
3	3131	3456	-9.4	30.616
10	3140	3557	-11.7	48.881
16	4879	4410	+10.6	49.970
27	4522	4782	-5.4	14.134
1	5715	5779	-1.1	0.704
28	6505	6239	+4.3	11.373
2	7812	8385	-6.8	39.217
7	9375	9442	-0.7	0.478
6	9681	10324	-6.2	40.089
9	10828	11104	-2.5	6.873
33	11804	12141	-2.8	9.342
4	13568	14905	-9.0	119.866
39	17974	17721	+1.4	3.625
42	19894	19894	0	0
41	20691	20605	+0.4	0.362
Total	152792	155864	-2.0	383.024

Table 9.4 Station 42

Hours 3, 12, 13, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	2365	3120	-24.2	182.779
3	3447	3456	-0.3	0.026
10	3523	3557	-1.0	0.316
16	3750	4410	-15.0	98.921
27	4715	4782	-1.4	0.950
1	5702	5779	-1.3	1.031
28	5157	6239	-17.3	187.683
2	9475	8385	-13.0	141.570
7	9568	9442	+1.5	1.680
6	10985	10324	+6.4	42.328
9	10810	11104	-2.6	7.790
33	12156	12141	+0.1	0.019
4	14724	14905	-1.2	2.194
39	17968	17721	+1.4	3.437
42	19894	19894	0	0
41	19904	20605	-3.4	23.871
Total	154143	155864	-1.1	694.593

Table 9.5 Station 42

Hours 5, 7, 16, & 24

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3137	3120	+0.5	0.096
3	3005	3456	-13.0	58.807
10	3073	3557	-13.6	65.957
16	5411	4410	+22.7	227.059
27	4878	4782	+2.0	1.924
1	4723	5779	-18.3	192.874
28	7000	6239	+12.2	92.834
2	6301	8385	-24.9	518.056
7	7917	9442	-16.2	246.186
6	9291	10342	-10.2	103.316
9	12548	11104	+13.0	187.830
33	13140	12141	+8.2	82.266
4	14328	14905	-3.9	22.359
39	17507	17721	-1.2	2.590
42	19894	19894	0	0
41	22948	20605	+11.4	266.452
Total	155101	155864	-0.5	2068.607

Table 9.6 Station 42

Hours 1, 9, 14, & 23

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3339	3120	+7.0	15.419
3	3501	3456	+1.3	0.590
10	3284	3557	-7.7	20.972
16	4100	4410	-7.0	21.764
27	5163	4782	+8.0	30.388
1	6196	5779	+7.2	30.125
28	6056	6239	-2.9	5.370
2	8450	8385	+0.8	0.497
7	10194	9442	+8.0	59.897
6	11024	10342	+6.6	47.461
9	11910	11104	+7.3	58.433
33	12662	12141	+4.3	22.363
4	15498	14905	+4.0	23.611
39	17971	17721	+1.4	3.530
42	19894	19894	0	0
41	19304	20605	-6.3	82.151
Total	158546	155864	+1.7	422.573

Table 9.7 Station 42

Hours 6, 10, 17, & 22

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3451	3120	+13.5	56.887
3	3803	3456	+10.0	34.760
10	4555	3557	+28.1	280.205
16	4751	4410	+7.7	26.349
27	5238	4782	+9.5	43.483
1	6245	5779	+8.1	37.603
28	6736	6239	+8.0	39.539
2	9408	8385	+12.2	124.906
7	10116	9442	+7.1	48.080
6	11410	10324	+10.5	114.242
9	11578	11104	+4.3	20.207
33	12426	12141	+2.3	6.689
4	16994	14905	+14.0	292.823
39	17976	17721	+1.4	3.673
42	19894	19894	0	0
41	20604	20605	0.0	0.000
Total	165275	155864	+6.0	1129.446

Table 9.8 Station 42

Hours 5, 8, 13, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3043	3120	-2.5	1.922
3	2972	3456	-14.0	67.687
10	2885	3557	-18.9	127.087
16	4133	4410	-6.3	17.341
27	4133	4782	-13.6	88.025
1	5222	5779	-9.6	53.652
28	6041	6239	-3.2	6.300
2	7586	8385	-9.5	76.074
7	8979	9442	-4.9	22.744
6	9308	10324	-9.8	100.030
9	10323	11104	-7.0	54.967
33	11430	12141	-5.9	41.622
4	12709	14905	-14.7	323.549
39	17996	17721	+1.6	4.259
42	19894	19894	0	0
41	20524	20605	-0.4	0.317
Total	147178	155864	-5.6	985.577

Table 10.1 Station 16

Hours 5, 8, 13, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3214	3120	+3.0	2.807
3	3359	3456	-2.8	2.735
10	3369	3557	-5.3	9.983
16	4410	4410	0	0
27	4618	4782	-3.4	5.622
1	5641	5779	-2.4	3.280
28	6547	6239	+4.9	15.195
2	8706	8385	+3.8	12.314
7	9819	9442	+4.0	15.032
6	10660	10324	+3.3	10.967
9	11264	11104	+1.4	2.314
33	12758	12141	+5.1	31.390
4	14189	14905	-4.8	34.419
39	19668	17721	+11.0	213.932
42	22384	19894	+12.5	311.769
41	22960	20605	+11.4	269.219
Total	163566	155864	+4.9	940.977

Table 10.2 Station 16

Hours 1, 9, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3498	3120	+12.1	45.702
3	3727	3456	+7.8	21.198
10	4019	3557	+13.0	59.888
16	4410	4410	0	0
27	4569	4782	-4.5	9.447
1	6252	5779	+8.2	38.691
28	6996	6239	+12.1	91.742
2	8133	8385	-3.0	7.584
7	9624	9442	+1.9	3.498
6	9531	10324	-7.7	60.904
9	10952	11104	-1.4	2.084
33	12314	12141	+1.4	2.468
4	14924	14905	+0.1	0.023
39	18009	17721	+1.6	4.675
42	20353	19894	+2.3	10.577
41	20182	20605	-2.1	8.679
Total	157493	155864	+1.0	367.160

Table 11.1 Stations 33, 27, & 4

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3100	3120	-0.6	0.128
3	3574	3456	+3.4	4.029
10	3726	3557	+4.8	8.030
16	4330	4410	-1.8	1.451
27	4782	4782	0	0
1	6210	5779	+7.5	32.144
28	6232	6239	-0.1	0.008
2	8692	8385	+3.7	11.240
7	9811	9442	+3.9	14.421
6	9951	10324	-3.6	13.476
9	11315	11104	+1.9	4.009
33	12141	12141	0	0
4	14905	14905	0	0
39	18259	17721	+3.0	16.333
42	20460	19894	+2.8	16.103
41	19791	20605	-4.0	32.157
Total	157279	155864	+0.9	153.529

Table 11.2 Stations 28, 2, & 42

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3032	3120	-2.8	2.482
3	3493	3456	+1.1	0.396
10	3624	3557	+1.9	1.262
16	4227	4410	-4.1	7.594
27	4484	4782	-6.2	18.570
1	6042	5779	+4.6	11.969
28	6239	6239	0	0
2	8385	8385	0	0
7	9583	9442	+1.5	2.106
6	9736	10324	-5.7	33.489
9	11121	11104	+0.1	0.026
33	12154	12141	+0.1	0.014
4	14372	14905	-3.6	19.060
39	17766	17721	+0.3	0.114
42	19894	19894	0	0
41	19253	20605	-6.6	88.712
Total	153405	155864	-1.6	185.794

Table 11.3 Stations 3, 7, & 33

Hours 4, 9, 15, & 20

Stations	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3012	3120	-3.5	3.738
3	3456	3456	0	0
10	3634	3557	+2.2	1.667
16	4213	4410	-4.5	8.800
27	4452	4782	-6.9	22.772
1	6031	5779	+4.4	10.989
28	6072	6239	-2.7	4.470
2	8436	8385	+0.6	0.310
7	9442	9442	0	0
6	9614	10324	-6.9	48.828
9	10908	11104	-1.8	3.460
33	12141	12141	0	0
4	14225	14905	-4.6	31.023
39	17726	17721	0.0	0.001
42	19920	19894	+0.1	0.034
41	19214	20605	-6.8	93.903
Total	152496	155864	-2.2	229.995

Table 11.4 Stations 32, 1, & 28

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3474	3456	+0.5	0.094
10	3643	3557	+2.4	2.079
16	4268	4410	-3.2	4.572
27	4487	4782	-6.2	18.198
1	5779	5779	0	0
28	6239	6239	0	0
2	8506	8385	+1.4	1.746
7	9467	9442	+0.3	0.066
6	9731	10324	-5.7	34.061
9	10929	11104	-1.6	2.758
33	12165	12141	+0.2	0.047
4	14289	14905	-4.1	25.458
39	17747	17721	+0.1	0.038
42	19973	19894	+0.4	0.314
41	19383	20605	-5.9	72.472
Total	153200	155864	-1.7	161.903

Table 11.5 Stations 3, 10, & 39

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3015	3120	-3.4	3.534
3	3456	3456	0	0
10	3557	3557	0	0
16	4204	4410	-4.7	9.623
27	4463	4782	-6.7	21.280
1	6006	5779	+3.9	8.702
28	6053	6239	-3.0	5.545
2	8466	8385	+1.0	0.782
7	9556	9442	+1.2	1.376
6	9699	10324	-6.1	37.837
9	11084	11104	-0.2	0.036
33	12079	12141	-0.5	0.317
4	14307	14905	-4.0	23.992
39	17721	17721	0	0
42	19785	19894	-0.5	0.597
41	19145	20605	-7.1	103.451
Total	152596	155864	-2.1	217.072

Table 12.1 Stations 32, 10, 27, 28, 7, 9, 4, & 41

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3599	3456	+4.1	5.929
10	3557	3557	0	0
16	4391	4410	-0.4	0.080
27	4782	4782	0	0
1	6265	5779	+8.4	40.887
28	6239	6239	0	0
2	8774	8385	+4.6	18.090
7	9442	9442	0	0
6	10017	10324	-3.0	9.105
9	11104	11104	0	0
33	12624	12141	+4.0	19.180
4	14905	14905	0	0
39	18413	17721	+3.9	27.003
42	20696	19894	+4.0	32.305
41	20605	20605	0	0
Total	158533	155864	+1.7	152.580

Table 12.2 Stations 32, 10, 27, 28, 7, 9, 4, & 41

Hours 1, 9, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3680	3456	+6.5	14.545
10	3557	3557	0	0
16	4475	4410	+1.5	0.949
27	4782	4782	0	0
1	6094	5779	+5.5	17.189
28	6239	6239	0	0
2	8023	8385	-4.3	15.638
7	9442	9442	0	0
6	9488	10324	-8.1	67.767
9	11104	11104	0	0
33	11984	12141	-1.3	2.026
4	14905	14905	0	0
39	17541	17721	-1.0	1.838
42	19983	19894	+0.4	0.400
41	20605	20605	0	0
Total	155022	155864	-0.5	120.352

Table 12.3 Stations 32, 10, 27, 28, 7, 9, 4, & 41

Hours 5, 8, 13, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3204	3456	-7.3	18.318
10	3557	3557	0	0
16	4415	4410	+0.1	0.006
27	4782	4782	0	0
1	5586	5779	-3.3	6.471
28	6239	6239	0	0
2	8198	8385	-2.2	4.185
7	9442	9442	0	0
6	10057	10324	-2.6	6.922
9	11104	11104	0	0
33	12287	12141	+1.2	1.767
4	14905	14905	0	0
39	19310	17721	+9.0	142.552
42	21410	19894	+7.6	115.517
41	20605	20605	0	0
Total	158221	155864	+1.5	295.738

Table 12.4 Stations 32, 10, 27, 28, 7, 9, 4, & 41

Hours 6, 7, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3052	3456	-11.7	47.294
10	3557	3557	0	0
16	5867	4410	+33.0	481.322
27	4782	4782	0	0
1	5347	5779	-7.5	32.258
28	6239	6239	0	0
2	6815	8385	-18.7	293.847
7	9442	9442	0	0
6	9227	10324	-10.6	116.630
9	11104	11104	0	0
33	12490	12141	+2.9	10.035
4	14905	14905	0	0
39	18368	17721	+3.7	23.636
42	20046	19894	+0.8	1.163
41	20605	20605	0	0
Total	154966	155864	-0.6	1006.184

Table 12.5 Stations 32, 10, 27, 28, 7, 9, 4, & 41

Hours 2, 7, 14, & 21

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3019	3456	-12.6	55.209
10	3557	3557	0	0
16	4984	4410	+13.0	74.653
27	4782	4782	0	0
1	5378	5779	-6.9	27.774
28	6239	6239	0	0
2	7350	8385	-12.3	127.647
7	9442	9442	0	0
6	10146	10324	-1.7	3.052
9	11104	11104	0	0
33	13201	12141	+8.7	92.598
4	14905	14905	0	0
39	19328	17721	+9.1	145.773
42	20599	19894	+3.5	24.976
41	20605	20605	0	0
Total	157759	155864	+1.2	551.682

Table 12.6 Stations 32, 10, 27, 28, 7, 9, 4, & 41

Hours 6, 9, 14, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3492	3456	+1.0	0.383
10	3557	3557	0	0
16	4057	4410	-8.0	28.311
27	4782	4782	0	0
1	6084	5779	+5.3	16.116
28	6239	6239	0	0
2	8536	8385	+1.8	2.703
7	9442	9442	0	0
6	10494	10324	+1.6	2.796
9	11104	11104	0	0
33	12349	12141	+1.7	3.551
4	14905	14905	0	0
39	18776	17721	+5.9	62.781
42	21105	19894	+6.1	73.722
41	20605	20605	0	0
Total	158647	155864	+1.8	190.363

Table 13.1 Stations 32, 3, 10, 16, 4, 39, 41, & 42

Hours 1, 9, 17, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3456	3456	0	0
10	3557	3557	0	0
16	4410	4410	0	0
27	4482	4782	-6.3	18.776
1	6061	5779	+4.9	13.796
28	7000	6239	+12.2	92.768
2	8001	8385	-4.6	17.582
7	9277	9442	-1.7	2.887
6	9473	10324	-8.2	70.152
9	10595	11104	-4.6	23.359
33	11908	12141	-1.9	4.479
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	154465	155864	-0.9	243.799

Table 13.2 Stations 32, 3, 10, 16, 4, 39, 41, & 42

Hours 5, 8, 13, 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3456	3456	0	0
10	3557	3557	0	0
16	4410	4410	0	0
27	4311	4782	-9.8	46.423
1	5422	5779	-6.2	22.027
28	6289	6239	+0.8	0.409
2	7915	8385	-5.6	26.395
7	9331	9442	-1.2	1.303
6	9727	10324	-5.8	34.533
9	10716	11104	-3.5	13.536
33	11939	12141	-1.7	3.365
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	153318	155864	-1.6	147.991

Table 13.3 Stations 32, 3, 10, 16, 4, 39, 41, & 42

Hours 1, 8, 13, 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3456	3456	0	0
10	3557	3557	0	0
16	4410	4410	0	0
27	4349	4782	-9.1	39.238
1	5796	5779	+0.3	0.048
28	6229	6239	-0.2	0.017
2	8113	8385	-3.2	8.821
7	9885	9442	+4.7	20.783
6	9782	10324	-5.2	28.414
9	10716	11104	-3.5	13.525
33	12337	12141	+1.6	3.167
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	154875	155864	-0.6	114.013

Table 13.4 Stations 32, 3, 10, 16, 4, 39, 41, & 42

Hours 6, 9, 14, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3120	3120	0	0
3	3456	3456	0	0
10	3557	3557	0	0
16	4410	4410	0	0
27	4583	4782	-4.2	8.304
1	6022	5779	+4.2	10.214
28	6078	6239	-2.6	4.179
2	8443	8385	+0.7	0.408
7	9564	9442	+1.3	1.584
6	10390	10324	+0.6	0.427
9	11307	11104	+1.8	3.709
33	12153	12141	+0.1	0.012
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	156208	155864	+0.2	28.836

Table 14.1 Stations 7, 6, 9, 33, 4, 39, 41, & 42

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32.	3092	3120	-0.9	0.245
3	3560	3456	+3.0	3.117
10	3716	3557	+4.5	7.124
16	4312	4410	-2.2	2.195
27	4569	4782	-4.5	9.503
1	6181	5779	+7.0	27.957
28	6224	6239	-0.2	0.038
2	8657	8385	+3.2	8.809
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	156447	155864	+0.4	58.988

Table 14.2 Stations 7, 6, 9, 33, 4, 39, 41, & 42

Hours 6, 9, 14, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3230	3120	+3.5	3.907
3	3418	3456	-1.1	0.417
10	3243	3557	-8.8	27.785
16	3951	4410	-10.4	47.763
27	4541	4782	-5.0	12.176
1	5948	5779	+2.9	4.926
28	6056	6239	-2.9	5.368
2	8308	8385	-0.9	0.714
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	154831	155864	-0.7	103.055

Table 14.3 Stations 7, 6, 9, 33, 4, 39, 41, & 42

Hours 6, 9, 15, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3328	3120	+6.7	13.891
3	3417	3456	-1.1	0.449
10	3571	3557	+0.4	0.059
16	4633	4410	+5.1	11.295
27	4609	4782	-3.6	6.258
1	5857	5779	+1.3	1.064
28	6477	6239	+3.8	9.054
2	8314	8385	-0.8	0.600
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	14905	14905	0	0
39	17721	17721	0	0
42	19894	19894	0	0
41	20605	20605	0	0
Total	156342	155864	+0.3	42.670

Table 15.1 Stations 3, 27, 28, 2, 7, 6, 9, & 33

Hours 4, 9, 15, & 20

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3079	3120	-1.3	0.533
3	3456	3456	0	0
10	3722	3557	+4.6	7.679
16	4300	4410	-2.5	2.727
27	4782	4782	0	0
1	6174	5779	+6.8	27.056
28	6239	6239	0	0
2	8385	8385	0	0
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	14524	14905	-2.6	9.746
39	18147	17721	+2.4	10.243
42	20393	19894	+2.5	12.533
41	19641	20605	-4.7	45.073
Total	155853	155864	-0.007	115.591

Table 15.2 Stations 3, 27, 28, 2, 7, 6, 9, & 33

Hours 6, 9, 14, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3272	3120	+4.9	7.409
3	3456	3456	0	0
10	3273	3557	-8.0	22.749
16	4033	4410	-8.5	32.149
27	4782	4782	0	0
1	5978	5779	+3.4	6.860
28	6239	6239	0	0
2	8385	8385	0	0
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	14183	14905	-4.8	34.982
39	18610	17721	+5.0	44.598
42	20870	19894	+4.9	47.924
41	20497	20605	-0.5	0.562
Total	156589	155864	+0.5	197.234

Table 15.3 Stations 3, 27, 28, 2, 7, 6, 9, & 33

Hours 6, 9, 15, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3388	3120	+8.6	22.994
3	3456	3456	0	0
10	3619	3557	+1.7	1.078
16	4734	4410	+7.3	23.758
27	4782	4782	0	0
1	5933	5779	+2.7	4.088
28	6239	6239	0	0
2	8385	8385	0	0
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	14343	14905	-3.8	21.195
39	18743	17721	+5.8	58.933
42	21380	19894	-7.5	111.055
41	21178	20605	+2.8	15.954
Total	159191	155864	+2.1	259.055

Table 15.4 Stations 3, 27, 28, 2, 7, 6, 9, & 33

Hours 5, 8, 13, & 19

Station	Computed Count	Actual Count	% Difference	Chi-Square Factor
32	3313	3120	+6.2	11.997
3	3456	3456	0	0
10	3111	3557	-12.5	55.957
16	4494	4410	+1.9	1.607
27	4782	4782	0	0
1	5671	5779	-1.9	2.014
28	6239	6239	0	0
2	8385	8385	0	0
7	9442	9442	0	0
6	10324	10324	0	0
9	11104	11104	0	0
33	12141	12141	0	0
4	13782	14905	-7.5	84.660
39	19546	17721	+10.3	187.912
42	21539	19894	+8.3	136.065
41	22256	20605	+8.0	132.218
Total	159585	155864	+2.4	612.429

Table 16

Rotated Factor Matrix for 24 Hours of Counts

Rotated Factor Matrix

Hour	1	2
1	0.67045	-0.71003
2	0.42779	-0.89506
3	0.32767	-0.92417
4	0.12265	-0.96975
5	0.77514	-0.50519
6	0.93255	-0.27733
7	0.91278	-0.25919
8	0.91546	-0.35726
9	0.88137	-0.41742
10	0.80087	-0.54343
11	0.80416	-0.55621
12	0.85602	-0.48129
13	0.93224	-0.33910
14	0.88944	-0.42793
15	0.93718	-0.32850
16	0.94211	-0.25569
17	0.93784	-0.28916
18	0.95159	-0.26667
19	0.94543	-0.31008
20	0.91956	-0.36823
21	0.92679	-0.34640
22	0.79700	-0.56011
23	0.83398	-0.51554
24	0.80457	-0.54222

Factor	Variance	Percent
1	16.48183	71.75
2	6.48866	28.25

Table 16.1

Factor Matrix for Odd Hours

Factor Matrix

Hour	1
1	0.92560
3	0.72546
5	0.92750
7	0.92918
9	0.97221
11	0.97290
13	0.98137
15	0.98117
17	0.96352
19	0.97970
21	0.97871
23	0.97667

Only 1 factor retained. No rotation will be made.

Table 16.2

Factor Matrix for Even Hours

Rotated Factor Matrix

Hour	1	2
2	0.47162	-0.87332
4	0.16229	-0.97222
6	0.94180	-0.23268
8	0.92146	-0.32914
10	0.82691	-0.50521
12	0.88162	-0.43261
14	0.91078	-0.37908
16	0.95525	-0.20550
18	0.96788	-0.21384
20	0.93467	-0.32776
22	0.82929	-0.51344
24	0.83197	-0.50572

Factor	Variance	Percent
1	8.37822	72.54
2	3.17122	27.46

Table 17

Factor Matrix for 16 Stations

Station	Factor Matrix 1
32	0.93486
3	0.98283
10	0.96125
16	0.92056
27	0.95123
1	0.96530
28	0.95285
2	0.94006
7	0.95352
6	0.96488
9	0.97439
33	0.97767
4	0.98928
39	0.98013
42	0.99100
41	0.97572

Only 1 factor retained. No rotation will be made.

Table 18

Relationships Between Factor Analysis and Estimate Accuracies, Four Station Tests, Tables 4.3.1 to 4.3.4

Station	Correlation From Table 17	Rank Among Stations	% Difference	Rank Among Stations
28	0.95285	1	-4.2	2
16	0.92056	4	+9.9	4
27	0.95123	2	+3.9	1
32	0.93486	3	-5.6	3

Station	Total Chi-Square Factor	Rank Among Stations
28	83.129	1
16	263.112	4
27	86.405	2
32	105.342	3

Table 19

Relationships Between Factor Analysis and Estimate Accuracies, Sixteen Station Tests, Tables 8.1 to 8.6

Station	Correlation From Factor Analysis	Rank Among Stations	% Difference	Rank Among Stations
32	0.93486	5	+3.0	5
3	0.98283	3	-2.1	2
16	0.92056	6	+5.8	6
2	0.94006	4	-2.5	3,4
4	0.98928	2	-2.5	
42	0.99100	1	-0.8	1

Station	Total Chi-Square Factor	Rank Among Stations
32	285.544	4
3	206.144	2
16	798.447	6
2	301.499	5
4	265.272	3
42	177.263	1

Algebraic Representation of the Estimation Process

This process was described on pages 30, 31, and 32 using the counts for station 42 to estimate the count for station 4.

Terms

${}_{x}H_{y}$ = Hourly Count, Hour x, Station y

EC_x = Estimated Count for Station x

Factors for the segments of hours of the day

F_1 = Factor 1 $\quad$ F_2 = Factor 2

F_3 = Factor 3 $\quad$ F_4 = Factor 4

$$F_1 = \frac{{}_{1}H_{42} + {}_{2}H_{42} + {}_{3}H_{42} + {}_{4}H_{42} + {}_{5}H_{42} + {}_{6}H_{42}}{{}_{1}H_{42}}$$

$$F_2 = \frac{{}_{7}H_{42} + {}_{8}H_{42} + {}_{9}H_{42} + {}_{10}H_{42} + {}_{11}H_{42} + {}_{12}H_{42}}{{}_{9}H_{42}}$$

$$F_3 = \frac{{}_{13}H_{42} + {}_{14}H_{42} + {}_{15}H_{42} + {}_{16}H_{42} + {}_{17}H_{42} + {}_{18}H_{42}}{{}_{17}H_{42}}$$

$$F_4 = \frac{{}_{19}H_{42} + {}_{20}H_{42} + {}_{21}H_{42} + {}_{22}H_{42} + {}_{23}H_{42} + {}_{24}H_{42}}{{}_{20}H_{42}}$$

$$EC_4 = (F_1 \cdot {}_{1}H_4) + (F_2 \cdot {}_{9}H_4) + (F_3 \cdot {}_{17}H_4) + (F_4 \cdot {}_{20}H_4)$$

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ABSTRACT

The highway agencies of the federal and state governments require traffic counts of selected roadways be taken every year. This information is used to provide statistics for Vehicle Miles of Travel(VMT) and usage for each type of roadway.

Presently, the bulk of these data is collected by use of portable and permanent traffic recorders. The permanent recorders are used to provide factors on time variations of traffic flows throughout the year. The portable recorders are moved to statistically selected locations to provide a sampling of all volumes of roads and streets.

In this study, estimates of traffic counts were obtained using the variations of traffic flow at selected locations. This was based on the assumption that the per cent of total traffic occurring in any given period is approximately the same along any route in an area.

The results were obtained by a predictive computer program. The variations in time of certain flows at specific locations were used to provide factors for estimating the traffic counts for other locations in the same general area.

The results showed this method of estimation was feasible. The estimated daily count for individual

locations was usually within 10% of actual volumes.

The hours chosen to provide counts to represent the traffic flow variations had a great effect upon the estimates. The higher volume hours seemed to provide better basis for estimates.

The location of the counting station also had a marked bearing upon the estimates. However, most of the counts of the stations showed very similar patterns in traffic volumes over a daily period.

This study showed the feasibility of estimating traffic counts by using the counts of a few stations in the same localized area. The hypothesis that traffic follows daily and hourly patterns which can be predicted has been substantiated by this study.

This method of estimation can be used with aerial counting of traffic to provide estimates of traffic for all roads in an area. This would be of great importance in obtaining yearly counts of the roadways in a large area.

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